OXY-ACETYLENE WELDING AND CUTTING

Oxy-Acetylene

WELDING AND CUTTING

LEARNING UNITS: RULES: STANDARDS

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PREFACE

INDUSTRIAL EDUCATION, whether classified as industrial arts or vocational training, should be as comprehensive in its offerings as possible to serve adequately the needs of those seeking technical training. With such a curriculum established, it then becomes necessary to analyze and appraise carefully and frequently the contents of the course, its objectives, and even the subject itself, in order to have explicit assurance that the material taught is in complete conformity with practices in industry. There is very little justification for a course if it does not provide the learner with training based on common industrial practices. It has been gratifying to note that, in general, industrial education has been and is keeping pace with current developments. This is evident since new courses and revision, expansion, and enrichment of existing subjects are constantly made in most schools. That is indeed a most admirable tribute to the men teaching in this field.

Wide adoption of welding in the modern shop program is a very good example of the versatility of the industrial-education curriculum. Until recently welding courses in public schools were extremely rare. However, with the development of this field, these courses were rapidly added wherever conditions permitted, until today such training is considered an essential phase of a shop program.

There are two important elements necessary for the successful teaching of welding: first, a competent instructor, and second, a definite plan of operation. The instructor should not only have a good knowledge of his field but he must be a competent welder. Simply informing a student how to do the operation is not enough; the telling must be co-ordinated, more or less, with the actual doing.

Unless the instructor can skillfully demonstrate what he desires the learner to acquire there is an unavoidable loss of direction and effectiveness needed in the learning process. The soundness of good teaching is further characterized by the skill with which the instructor can analyze, interpret, and correct the various students' individual or common welding difficulties, so troublesome to all beginners.

A good welding program necessitates a course of study as well organized as any other shop subject. Without some definite pattern of procedure, considerable waste of time and effort by the student will inevitably result. Furthermore, since welding supplies are costly, promiscuous welding simply accelerates needless expense. Careful observation over a period of many years has proved conclusively that a student makes greater and better progress if definite objectives are imposed and he is unequivocally made to adhere to a plan to achieve these goals.

Supplementing good instruction, there must be distributed over the training period sufficient related information of a technical and general nature to give the student enough knowledge of special welding techniques and their application to industry so that the acquisition of skills becomes more meaningful. In welding, students usually progress according to their capacities, and, although occasional group discussions of common problems are necessary, the use of a modern, practical text gives the individual an opportunity to study at will whenever the need arises. The purpose of this material, therefore, is to provide welding students with sufficient information and guidance to enable them to master welding skills more easily and purposefully.

To those who were instrumental in making this text possible, I am extremely thankful. Special acknowledgment is particularly given to the following for their splendid co-operation: Linde Air Products Co., Norton Company, Modern Engineering Co., The Bastian Blessing Co., Purity Cylinder Gases, and International Acetylene Association.

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INSTRUCTIONS TO WELDING STUDENTS

THE SERIES of lessons in this text represents the scope of work which must be mastered if you expect to become a welder. Each Unit is to be carried out in the order it appears, with special effort taken to develop the necessary skill required for the particular function taken up in the lesson. It is especially important that you form the habit of analyzing your welds, because rapid progress necessitates an exacting knowledge of your difficulties. If you know what is wrong, it will be easy enough to work out the proper technique for correcting the fault.

How to Use the Book

The entire Unit should be read first. When you are familiar with its contents, answer the questions which appear at the end of the material. The answers to these questions are not to be copied verbatim from the text but must be written out in your own words. When the questions have been answered, bring them to your instructor for correction. If the instructor finds that you have an understanding of the material, he will give you permission to proceed with the welding exercise. If a new technique is involved in the Unit, the instructor will give you an actual demonstration showing how this new manipulation is to be carried out.

Test each joint after it is welded as explained in the assignment, and permit the instructor to see the tested joint so that he may advise you of your faults. Do not ever be in too great a rush to complete a job. *Remember, in learning to weld it is not a question of how much you can do but rather how well you can perform the task.*

Unit 1

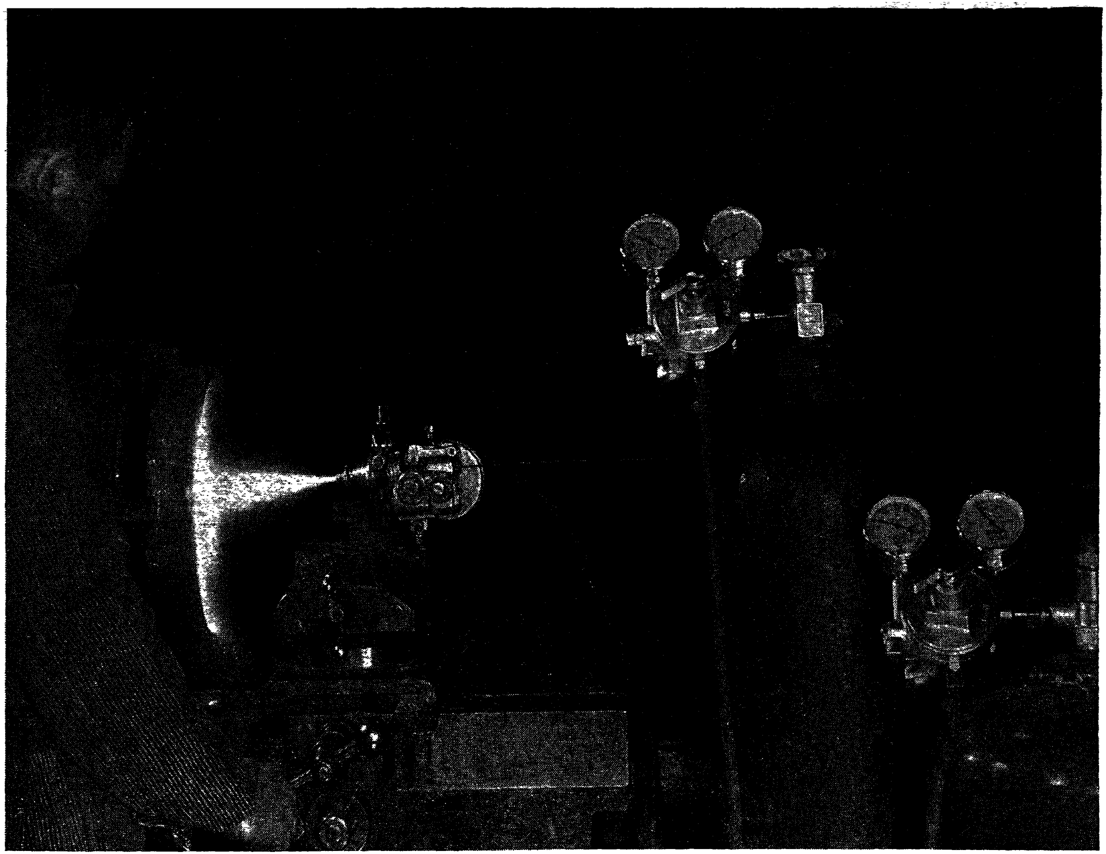
OXY-ACETYLENE WELDING

THE BLOWPIPE, which was the forerunner of our present-day welding torch, was used to some extent for various metalworking processes in the early history of our civilization. It was not until the latter part of the nineteenth century that the gas acetylene was produced in sufficient quantity to make this type of welding possible on a large scale. With the turn of the century more and more steel came into use for fabricating countless articles, and consequently, an extensive demand for welding resulted. Although there are other means of fastening metal pieces together welding makes the operation easier and much faster.

There are many different types of welding processes but the two most commonly used are the oxy-acetylene and electric. Some controversial issues frequently arise in which claims are made that one is superior to the other. Such arguments can be best dispelled by pointing out that each is in itself important to industrial fields. Each has a large area of its own and while one may have greater advantages for one type of work, the other may be more adaptable for other purposes.

Oxy-Acetylene Welding

Welding is a process of uniting two pieces of metal by means of heat to form a solid section. In former days the blacksmith did all welding by hammering two pieces of heated metal until the junction formed. Although this method was satisfactory for the particular work carried out in that period, present-day welding technique is much better from the standpoint of efficiency, time saving, and economy. Moreover, numerous metals can now be joined that never could be welded by the old method.



COURTESY PURITY CYLINDER GASES

The process of oxy-acetylene welding is possible because of the principle that when oxygen and acetylene are united in correct proportions and burned, the resulting flame is one of the hottest known. This flame, which reaches a temperature of 6300°F., melts all commercial metals to such a molten state that the metal actually flows together to form a complete bond without application of any mechanical pressure or hammering. In most instances, some extra metal in the form of a wire rod is added to the molten metal in order to build the seam up slightly for greater strength. On very thin material the edges are usually flanged and just melted together. In either case, if the weld is performed correctly, the section where the bond is made will be as strong as the base metal itself.

With the oxy-acetylene flame such metals as iron, steel, cast iron, copper, brass, aluminum, bronze, and other alloys may be welded. In many instances dissimilar metals may be joined, such as steel and cast iron, brass and steel, copper and iron, brass and cast iron. The oxy-acetylene flame is also employed for a variety of other purposes, notably for cutting metal, case hardening, annealing, etc. It is used for several types of metallic spray guns which spray fine particles of molten metal on worn surfaces that need refacing or building up.

Learning to Weld

Welding is an art that may be acquired by anyone who is actually interested in this field and who will patiently and conscientiously carry out the necessary instructions. Welding cannot be learned by just following a few regulations and applying a few motions of the torch on the metal. Constant practice is very essential. The beginner will experience some difficulty at first in making the welded joint hold, but as he develops the proper technique of welding he will overcome this problem. To prevent frequent occurrences of a bad weld, the student should test the strength of every welded joint, analyze the defects, and repeat the job until it has been mastered.

The following are a few fundamental rules which every student should keep in mind while learning to weld:

1. Strictly observe all safety rules, as there are dangers involved.

2. Be sure you are using the proper-sized tip for the metal which is to be welded.

3. Ascertain at all times, prior to lighting a torch, whether or not the tip is absolutely clean. It is almost impossible to obtain a good weld with a dirty tip.

4. See that you are using the correct gas pressure for the particular metal to be welded.

5. Learn to relax at the welding bench. One of the greatest difficulties of most beginners is holding the torch too tightly, cramping the muscles. This will tire a welder very quickly and prevent him from holding a steady flame on a direct line with the section to be welded.

6. Never attempt something new unless you are positive you know what is to be done.

7. Remember, a lighted torch is not dangerous if properly handled, but may prove disastrous if carelessly and improperly used.

QUESTIONS

1. Why is welding so important to the industrial field?

2. List as many products as you are familiar with that are fabricated by welding.

3. Name two general types of welding.

4. Why is the present type of welding more efficient than the old blacksmith method?

5. Name some of the metals that can be satisfactorily welded.

6. Name two other function of oxy-acetylene besides metal welding.

7. Why is a filler rod used in welding?

8. Why is constant practice essential in acquiring welding skill?

9. Why is it important that a beginner test all his welds?

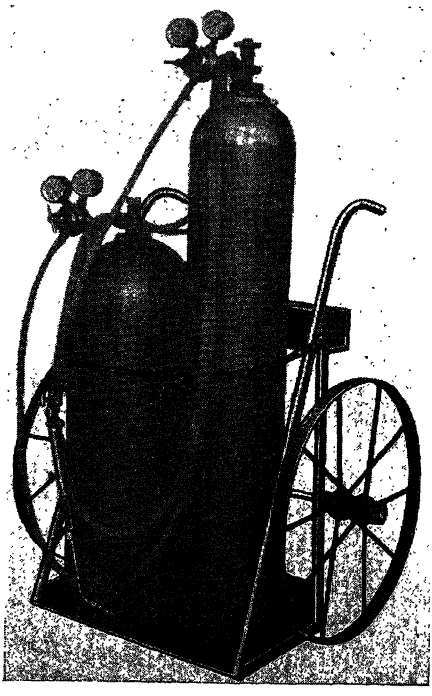
10. Why should a welder be concerned about safety measures?

Unit 2

WELDING APPARATUS

A SINGLE WELDING apparatus consists of a torch with an assortment of different-sized tips; two lengths of hose, one red for the acetylene and the other green for the oxygen; two pressure regulators; two cylinders, one containing acetylene and the other oxygen; a pair of dark-colored goggles; and a spark-lighter.

As a rule, the cylinders are chained to a two-wheel truck to permit moving of the equipment to any desired place. When considerable welding is done, such as in industry or in school training shops where a great many torches are used, the cylinders are connected to a manifold with pipe lines carrying the gas to the welding stations. Each bench is equipped with its own oxygen and acetylene line gauges, hose, and torch.



COURTESY BASTIAN-BLESSING COMPANY AND PURITY CYLINDER GASES

Fig. 1. Welding Apparatus on Truck

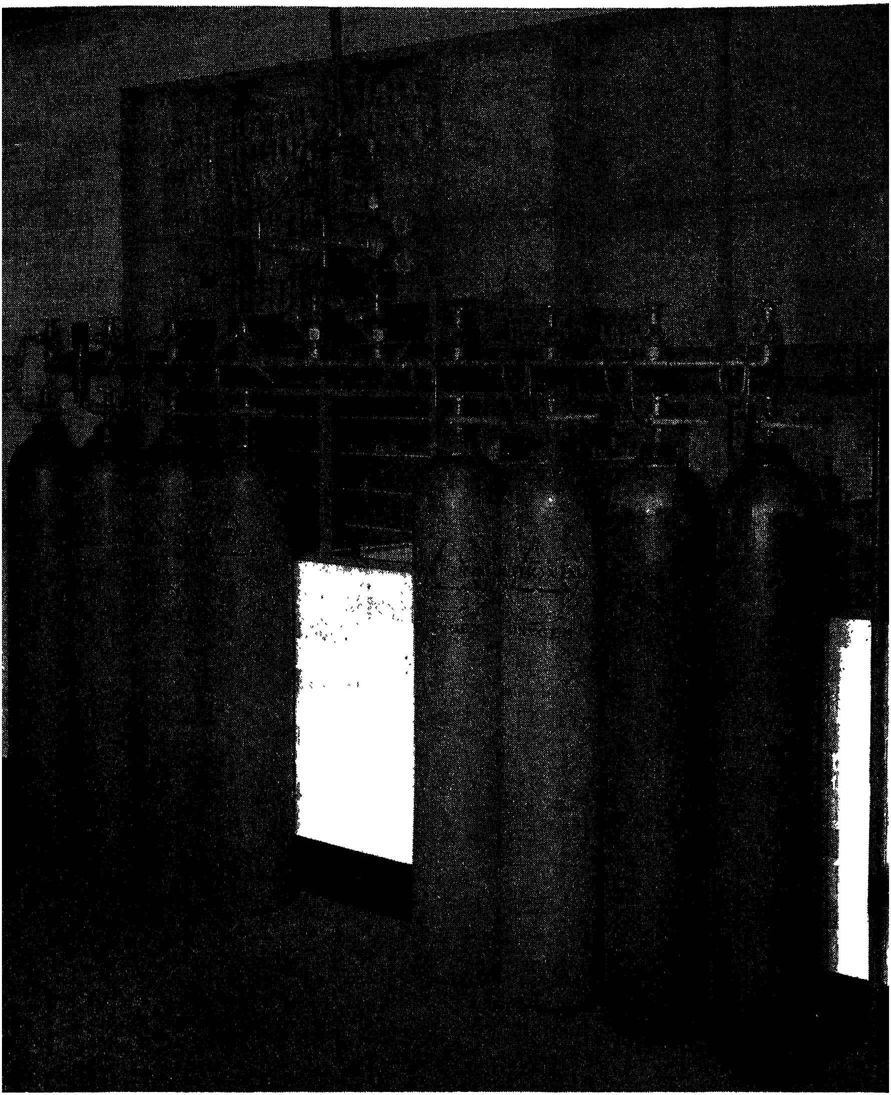


Fig 2. Oxygen Manifold

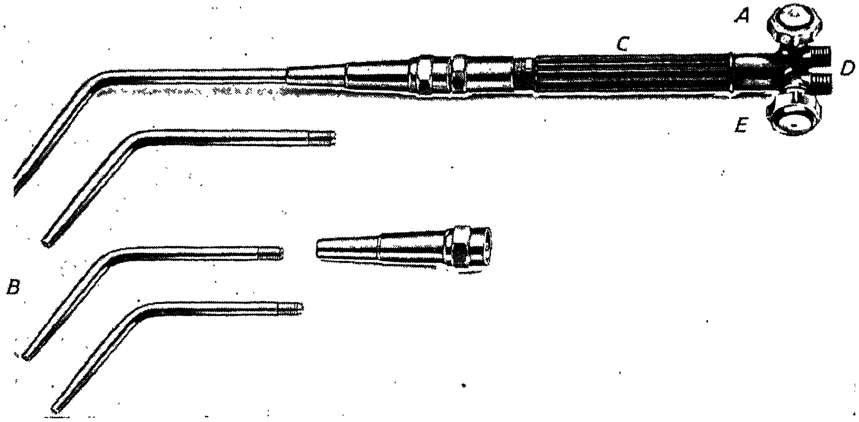


Fig. 3. Hand Welding Torch. *A*—Acetylene Needle Valve. *B*—Welding Tips. *C*—Torch Handle. *D*—Hose connections. *E*—Oxygen needle valve.

Welding Torch

The torch is an instrument used for mixing acetylene and oxygen in nearly equal quantities and bringing the gas to the end of a tip, where it is burned.

The torch consists of a handle through which two brass tubes pass, one for the oxygen and the other for the acetylene; a mixing head where these two gases are united; and a removable, tapered tip. At the rear end of the handle there are two needle valves, one which regulates the flow of oxygen and the other the acetylene. On the rear end of the torch there are also two fittings for connecting the two hose. In order to eliminate any danger of interchanging the hose, the oxygen fitting is made with a right-hand thread and the acetylene with a left-hand thread.

Oxygen and Acetylene Hose

A special nonporous hose is used for welding. The green, oxygen hose and the red, acetylene hose correspond to the respective colors of the pressure regulators. This hose comes in sizes of 3⁄16″, 1⁄4″, 3⁄8″, and 1⁄2″ in diameter.

A standard connection is used to attach the hose to the regulator and torch. This connection consists of a nipple which is forced into the hose and a nut that connects the nipple to the regulator and torch. The acetylene nut may be distinguished from the oxygen by the groove that runs around the center, indicating a left-hand thread. A clamp of some type is generally used to squeeze the hose around the nipple to prevent it from working loose.

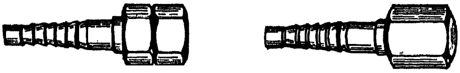

Acetylene *Oxygen*

Fig. 4. Hose Connections

Pressure Regulator

The oxygen and acetylene pressure regulators are required to perform two functions. They must reduce the cylinder pressure to the required working pressure and also produce a steady flow of gas under varying cylinder pressures. To illustrate this more clearly, let us assume that the oxygen in the cylinder has a pressure of 1800 pounds per square inch, and a pressure of 6 pounds at the torch is needed. The regulator must maintain a constant pressure of 6 pounds even if the cylinder pressure drops down to 500 pounds.

A regulator has two gauges, one which indicates the actual pressure in the cylinder and the other which shows the working pressure that is being used at the torch. The oxygen high-pressure gauge is graduated to 3000 pounds and the working pressure gauge generally to 50 pounds. The acetylene pressure gauge is graduated to 500 pounds with a 30-pound, working pressure gauge.

The working pressure on both the acetylene and oxygen gauges is adjusted by means of a hand screw, generally referred to as the adjusting screw. To obtain the desired pressure on the working gauge, the adjusting screw is turned in, that is, to the right (clockwise). When the screw is turned out (counter-clockwise), so that it runs free, it closes the valve mechanism on the inside of the regulator, thereby shutting off the flow of gas.

The most important thing to remember when using the regulator is to make absolutely certain that the adjusting screw is released (turned out) before the cylinder valve is opened. If the adjusting screw is not released and the cylinder valve opened, the tremendous pressure of the gas in the cylinder is forced on to the working pressure gauge, resulting, possibly, in damaging the regulator.

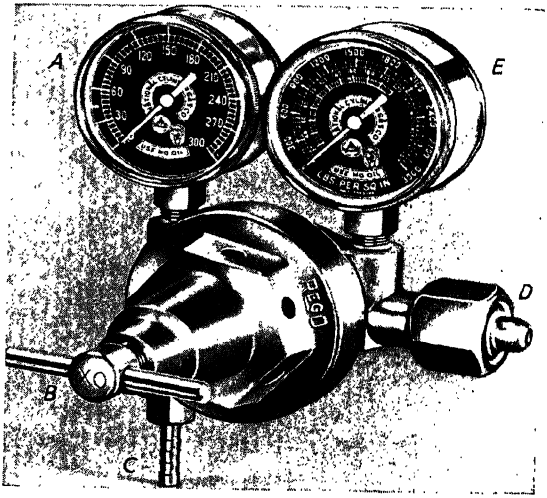


Fig. 5. Pressure Regulator. *A*—Working pressure gauge. *B*—Adjusting screw. *C*—Hose connection. *D*—Cylinder connection. *E*—Cylinder pressure gauge.

The Oxygen Cylinder

Oxygen cylinders are made from seamless, drawn steel and tested with a water pressure of 3360 pounds per square inch. The cylinders are equipped with a high-pressure valve which may be opened by turning the hand wheel on top of the cylinder. This valve should always be opened by hand and not with a wrench. The hand wheel must be turned slowly to permit a gradual pressure load on the regulator, and then opened as far as the valve will turn, to full gas pressure.

There are two common sizes of oxygen cylinders. The large size, which is the one popularly used by industrial plants and shops consuming large quantities of gas, is filled with 220 cubic feet of oxygen. The smaller cylinder contains 110 cubic feet.

Cylinders are charged with oxygen at a pressure of 2000 pounds per square inch at a temperature of 70° F. Since the pressure of gas will vary with the temperature, all oxygen cylinders are equipped with a fusible plug (safety nut) that will burst and permit the oxygen to drain slowly in event the temperature increases the pressure beyond the safety load of the cylinder. Thus, if a cylinder were exposed to a hot flame the safety nut would relieve the pressure before causing the cylinder to explode.

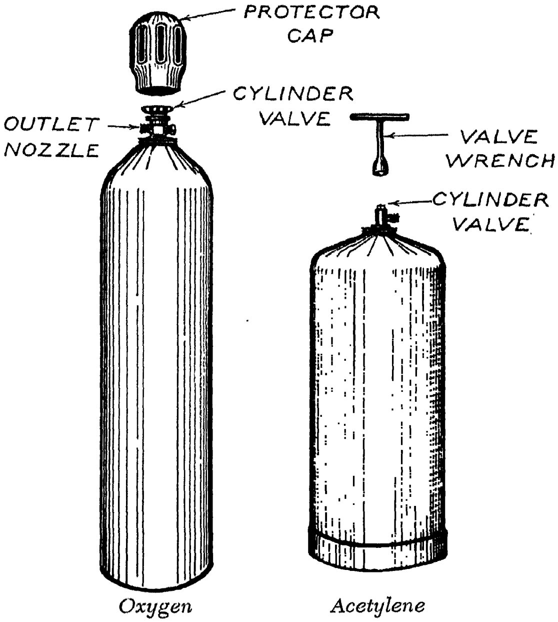


Fig. 6. Oxygen and Acetylene Cylinders

A protector cap which screws onto the neck ring of the cylinder is furnished to protect the valve from any damage. This cap should be in place when the cylinders are not in use. Cautions like this are things which mark the good welder.

The Acetylene Cylinder

The average acetylene cylinder contains approximately 125 cubic feet of free acetylene under an initial pressure of 250 pounds per square inch at 70° F. Acetylene is very inflammable and highly explosive. To insure safety in storing this gas, the cylinder is packed with a porous material and the packing saturated with acetone. This is a chemical liquid that dissolves or absorbs large quantities of acetylene under pressure without changing the nature of the gas itself.

The acetylene cylinder is also equipped with a fusible plug to relieve any excess pressure if the cylinder should be subjected to undue heat, any mechanical pressure, or hammering.

Goggles

An oxy-acetylene-torch flame produces light rays of great intensity and also heat rays which, if exposed to the naked eye, may eventually prove destructive to the eye tissues. Consequently, a welder should always wear goggles of a suitable, approved, colored glass. The density of the colored lenses should be such that no more of the light rays are shut off than are necessary to the welder. One test which a welder may perform to check the suitability of the colored lenses is to use one pair of goggles for a few minutes while welding and then remove them, noting whether or not white spots dance before his eyes. If these white spots are noticeable the lenses do not provide sufficient protection, and a darker shade should be used.

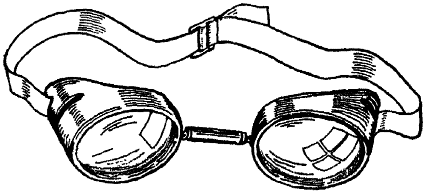


Fig.7. Welding Goggles

Goggles also protect the eyes from flying sparks and pieces of molten metal that may splatter around.

Sparklighter

The sparklighter is the implement used for igniting the torch. A welder should form the habit of always employing a sparklighter to light a torch and never resorting to matches. The use of matches for this purpose is very dangerous because the puff of the flame produced by the ignition of the acetylene flowing from the tip is likely to burn the hand.

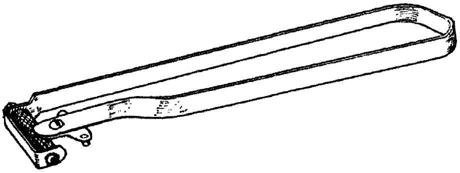


Fig. 8. Sparklighter

QUESTIONS

1. State the function of the needle valves on a welding torch.

2. Why are the oxygen and acetylene hose fittings made with different screw threads?

3. What is the function of a pressure regulator?

4. What is the function of each gauge on a regulator?

5. State the function of the adjusting regulator screw on a pressure regulator.

6. Why must the adjusting screw be released before a cylinder valve is opened?

7. What safety devices are used to prevent cylinders from exploding if subjected to intense pressure?

8. Why is acetone used in an acetylene cylinder?

9. What is the purpose of the protector cap on a cylinder?

10. Why is it dangerous to light a torch with a match?

Unit 3

SETTING UP THE WELDING APPARATUS

ALL WELDERS should be familiar with the method of putting together the welding apparatus. A certain sequence of operation must be followed if the equipment is to be properly and safely connected. As a rule the equipment is assembled as follows:

1. Fasten cylinders to truck, etc.
2. "Crack" cylinder valves.
3. Attach pressure regulators.
4. Connect hose to regulators.
5. Connect hose to torch.

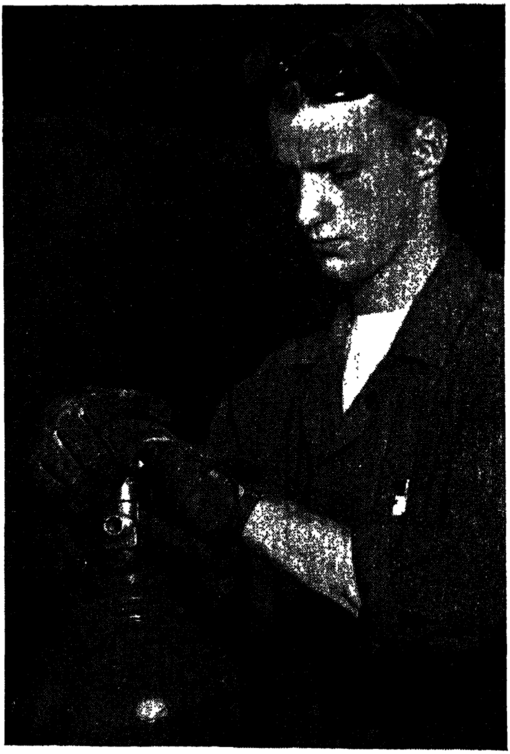


Fig. 9. Cracking Cylinder Valve

Step 1. CHAINING CYLINDERS

Fasten the cylinders securely to a truck or to some other fixed object where they are to be located. Remove the protector cap from each cylinder and closely examine the outlet nozzles. Make sure the connection seat or screw threads are not damaged. A damaged screw thread is apt to ruin the regulator nut, while a poor connection seat will cause the gas to leak.

Step 2. "Cracking" Cylinder Valve

Particles of dirt frequently collect in the outlet nozzle of the cylinder valve. This dirt, if not cleaned out, will work into the regulator when the pressure is turned on. To avoid any possibility of dirt clogging up any passage, the valves of each cylinder should be opened for just an instant. Then with a clean cloth the connection seat should be wiped out.

Step 3. Attaching Pressure Regulators

Connect the oxygen pressure regulator to the oxygen cylinder and the acetylene regulator to the acetylene cylinder. Use a close-fitting wrench to tighten the nuts, and exert care to avoid crossing the threads. A proper wrench should always be used to tighten the nuts, as a loose-fitting wrench will eventually ruin the corners of the regulator nuts. See Fig. 10.

Step 4. Connecting Hose to the Regulators

Connect the green hose to the oxygen regulator and the red hose to the acetylene regulator. See Fig. 11. Check the adjusting screw on each regulator to make certain that it is released, and then open the cylinder valves. (The oxygen valve should be opened all the way, while one turn of the acetylene cylinder valve will be sufficient.) Then blow out any dirt that may be lodged in the hose by opening the regulator adjusting screws and promptly closing them again when the hose has been cleaned out. See Fig. 12.

Step 5. Connecting Hose to the Torch

The hose is connected to the respective fittings on the torch, the red hose to the needle valve fitting, marked "AC," and the green hose to the oxygen needle valve, marked "OX." See Fig. 13.

Testing for Leaks

All new welding apparatus needs to be tested for leaks before being operated. Periodically thereafter it is advisable to apply this same test in order to insure that no leakage has developed. A leaky

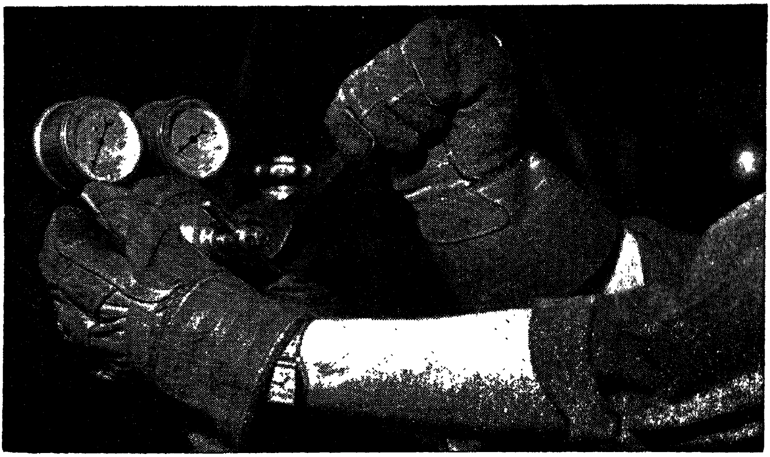


Fig. 10. Fastening Regulator to Cylinder

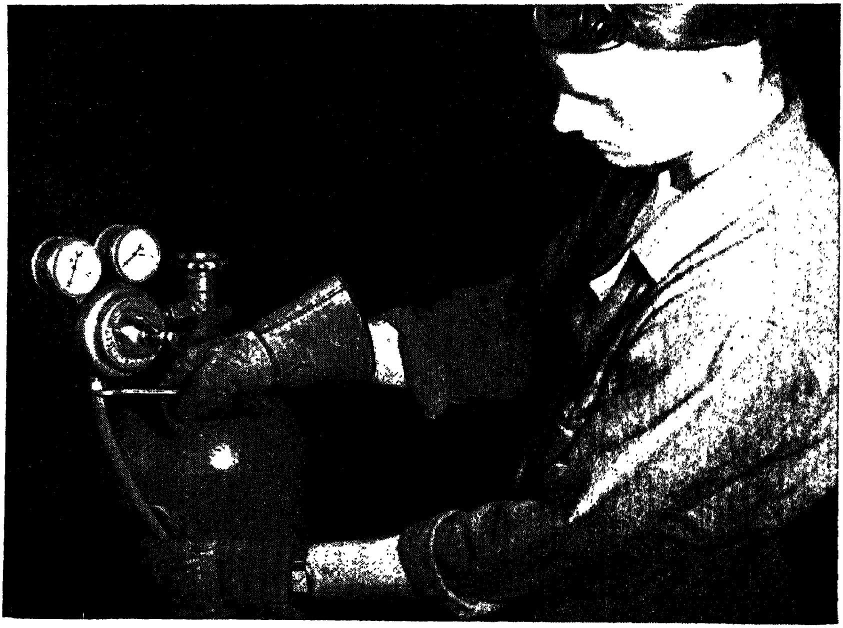


Fig. 11. Connecting Hose to Regulator

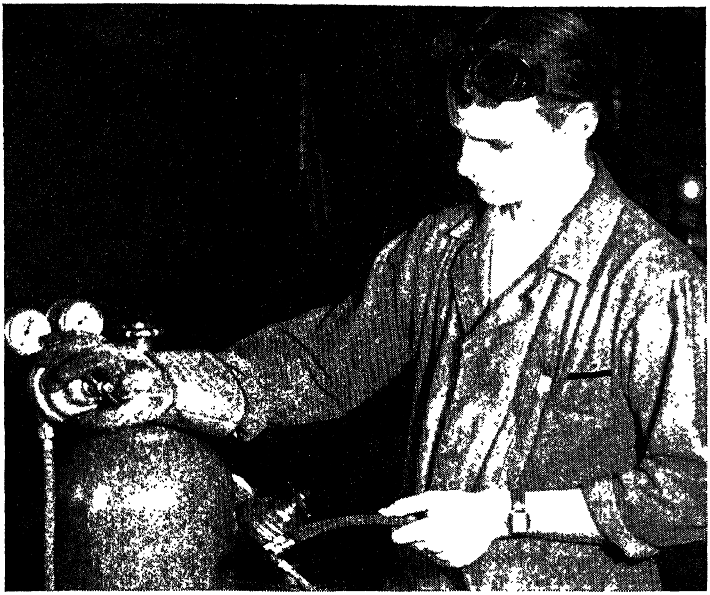


Fig. 12. Blowing out Hose

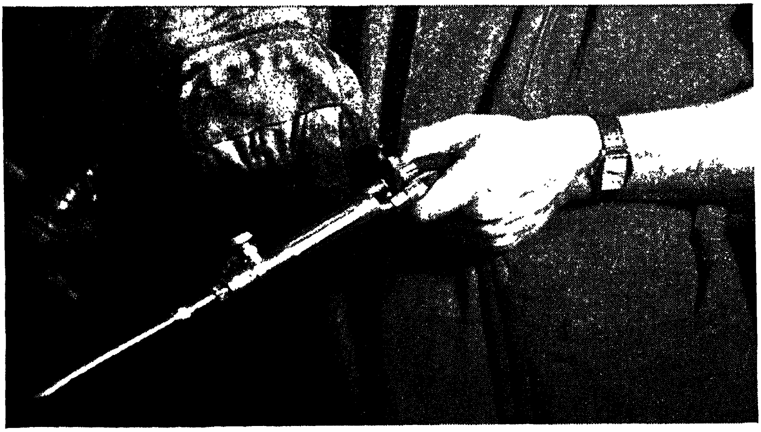


Fig. 13. Connecting Hose to Torch

apparatus is very dangerous, since a fire may develop. Furthermore, leaks mean wasted gas.

The proper method of testing for leaks is to apply soapsuds with a small brush to all connections. Under no circumstances should a flame be used. A leak will be easily disclosed by the formation of bubbles. To remedy any leakage, tighten up the connections a little with a wrench. If this does not stop the leakage, shut off the gas pressure, open the connections, and examine the screw threads. Old hose should be tested very closely, since it has a tendency to become porous.

QUESTIONS

1. Why should the cylinders be securely fastened before being used?
2. Why should the outlet nozzles be examined closely?
3. What is meant by the term "cracking the valve"? Why is this done?
4. Name the proper order of setting up the welding apparatus.
5. Why should a tight-fitting wrench be used in fastening all connections?
6. Why should a flame never be used in testing for leaks?
7. What is the proper method of testing for leaks?

Unit 4

LIGHTING, ADJUSTING, AND SHUTTING OFF FLAME

THIS LESSON should be studied very carefully, since the first operation at the welding bench is to be performed. The lesson will be supplemented by actual demonstrations on the correct method of lighting a torch, adjusting for a neutral flame, and shutting off the torch. Be sure you are familiar with the procedure for doing this task before asking for a demonstration from the instructor.

Selecting the Proper Welding Tip

The first problem confronting a welder is the selection of the correct tip to use. The size of tip to be employed will depend upon the thickness of the metal to be welded. If very light sheet iron is

TABLE I

TIP NUMBER	THICKNESS OF METAL—INCHES	OXYGEN PRESSURE—POUNDS	ACETYLENE PRESSURE—POUNDS	ACETYLENE CONSUMPTION
00	Very light	1	1	
0	Very light	2	1	
1	1/16	2	1	1.3
2	3/32	4	2	4.5
3	1/8	6	3	6.5
4	3/16	8	4	10.
5	5/16	10	5	15.
6	3/8	12	6	22.
7	1/2	14	6	30.
8	5/8	16	6	42.
9	3/4	18	6	58.
10	1 up	20	6	73.

to be welded, a tip having a small orifice is used, while a large-sized tip is needed for thick metal.

The size of the opening is marked on the tip with a number. The method of numbering the sizes depends largely on the manufacturer of the welding equipment. TABLE I illustrates the sizes of tips for various thicknesses of metals used in one particular make of tip. The table also shows the approximate working pressure required when using these tips.

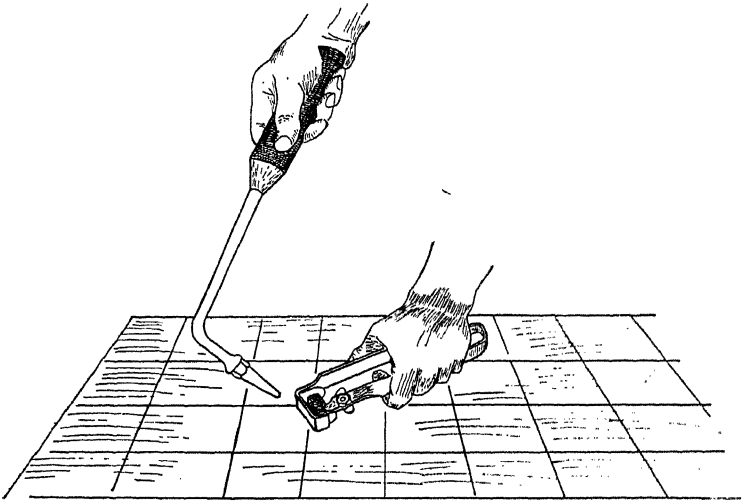


Fig. 14. Lighting the Torch

It is very important that the correct tip, with the proper working pressure, be used if the metal is to be welded satisfactorily. If too small a tip is employed, the heat will not be sufficient to fuse the metal at the proper depth. When the tip is too large, the heat is too great, thereby burning holes in the metal. A good weld must have the right penetration and smooth, even, overlapping ripples. Unless the conditions are just right, it is impossible for the torch to function the way it should, and, consequently, the weld will be poor.

Lighting the Torch

Select a tip for welding   or 1/16″ metal and screw it into the torch. Open the oxygen and acetylene cylinder valves as previously described, and set the working pressure to correspond to the size of tip that is to be used.

Turn the acetylene needle valve approximately three quarters of a turn. With the sparklighter, ignite the acetylene as it leaves the tip. See Fig. 14. Do this as rapidly as possible to avoid unnecessary wasting of gas. If insufficient acetylene is turned on, the flame will produce considerable smoke; therefore quickly turn on more acetylene until the flame has a slight tendency to jump away from the tip.

Flame Adjustment

With the acetylene burning, gradually open the oxygen needle valve until a well-defined white cone appears near the tip, surrounded by a second, bluish cone that is faintly luminous. This is known as a neutral flame and is so called because there is an approximate one-to-one mixture of acetylene and oxygen. The brilliant white cone should be from 1/16″ to 3/4″ long, depending on the tip size.

Any variation from the one-to-one mixture will alter the characteristics of the flame. If the proportion consists of a slight excess of acetylene, then the flame is carbonizing or reducing. This flame can easily be identified by the existance of three flame zones instead of the usual two, found in the neutral flame. The end of the brilliant white cone is no longer as well defined, and it is also surrounded by an intermediate white cone, which has a feathery edge in addition to the usual bluish outer envelope.

When an excess amount of oxygen is forced into the mixture, the resulting flame is said to be oxidizing. This flame resembles the neutral flame slightly, but has a shorter and more pointed inner cone whose color changes from a brilliant white to almost purple.

A beginner will probably have a little difficulty at first in making the correct adjustment, but if the characteristics of the carbonizing and oxidizing flames are understood, the adjustment for a neutral flame will be relatively simple. As an aid in becoming familiar with the effects of these various flames, try the following experiments:

CARBONIZING FLAME

Secure a piece of scrap metal. Light the acetylene and turn on the oxygen until a white cone appears on the end of the tip enveloped by another fan-shaped cone which has a feathered edge.

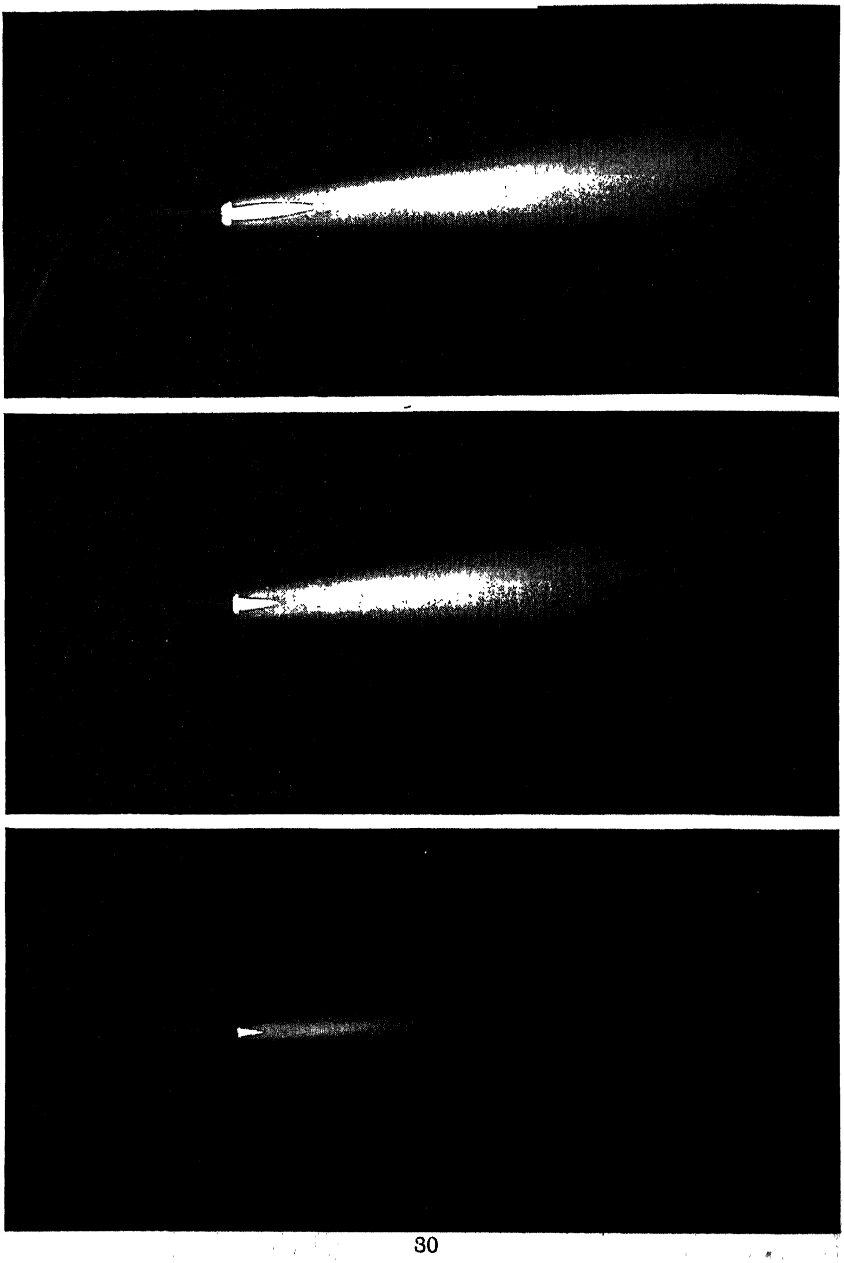


Fig. 15. Types of Welding Flames

described, and set the working pressure to correspond to the size of tip that is to be used.

Turn the acetylene needle valve approximately three quarters of a turn. With the sparklighter, ignite the acetylene as it leaves the tip. See Fig. 14. Do this as rapidly as possible to avoid unnecessary wasting of gas. If insufficient acetylene is turned on, the flame will produce considerable smoke; therefore quickly turn on more acetylene until the flame has a slight tendency to jump away from the tip.

Flame Adjustment

With the acetylene burning, gradually open the oxygen needle valve until a well-defined white cone appears near the tip, surrounded by a second, bluish cone that is faintly luminous. This is known as a neutral flame and is so called because there is an approximate one-to-one mixture of acetylene and oxygen. The brilliant white cone should be from 1/16″ to 3/4″ long, depending on the tip size.

Any variation from the one-to-one mixture will alter the characteristics of the flame. If the proportion consists of a slight excess of acetylene, then the flame is carbonizing or reducing. This flame can easily be identified by the existance of three flame zones instead of the usual two, found in the neutral flame. The end of the brilliant white cone is no longer as well defined, and it is also surrounded by an intermediate white cone, which has a feathery edge in addition to the usual bluish outer envelope.

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CARBONIZING FLAME

Secure a piece of scrap metal. Light the acetylene and turn on the oxygen until a white cone appears on the end of the tip enveloped by another fan-shaped cone which has

To secure a soft neutral flame it is essential, first, to see that the mixture is correct and, second, that the tip is absolutely clean. Even if the proportion of acetylene and oxygen is right, a good weld is difficult to achieve unless the opening in the tip permits a free flow of gases. Any foreign matter in the tip will simply restrict the source of heat necessary to melt the metal.

Flame Control

Once the flame has been properly set it does not mean that further adjustments are unnecessary. From time to time, as the welding progresses, it is necessary to glance at the flame to be certain that the mixture has not altered. Changes in the flame will occur as a result of some slight fluctuation in the flow of the gases from the regulators. A slight turn of one needle valve or the other will quickly readjust the flame.

In the course of welding a job, a torch may occasionally start "popping." This noise is an indication that there is an insufficient amount of gases flowing to the tip. Such popping can be stopped by opening both the oxygen and acetylene needle valves to a greater extent.

Shutting off the Torch

The following order should be observed in shutting off a torch:

1. Close the acetylene needle valve first.

The acetylene needle valve is closed first, since shutting off the flow of this gas will immediately blow out the flame, whereas if the oxygen is shut off first, the acetylene will continue to burn, throwing off a great deal of smoke and soot.

2. Close the oxygen needle valve.

3. If the entire welding unit is to be shut down, shut off both the acetylene and the oxygen cylinder valves. Then release the adjusting screw on the pressure regulators.

4. Remove the pressure on the working gauges by opening the needle valves until the lines are drained. Then promptly close the needle valves.

QUESTIONS

1. What governs the size of the tip which should be used?
2. Why must the working pressure be correct for the size of tip used?
3. How can you determine the amount of acetylene to turn on at the needle valve control when lighting the torch?
4. What is meant by an oxidizing flame?
5. What is a carbonizing flame?
6. How can you distinguish these flames from the neutral flame?
7. How can you determine when you have a neutral flame?
8. Why should the acetylene needle valve be closed first in shutting off the torch?
9. What is the difference between a harsh and soft flame?
10. What will cause a torch to "pop"?

Unit 5

WELDING METAL WITHOUT USING FILLER ROD

If you are able to light a torch and adjust the mixture for a neutral flame, the next operation will be to fuse two pieces of metal. This is to be done without the use of any filler rod.

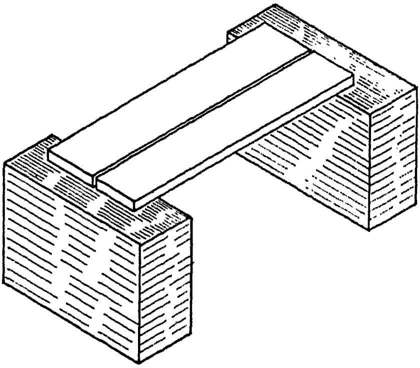

Fig. 16. Position of Plates for Welding

Practice Weld

Secure two pieces of metal, approximately 1/16" or 1/8" in thickness and 5 inches in length. Be sure that the surfaces are free from oil, dirt, etc. Lay the pieces of metal on two bricks as shown in Fig. 16, with their edges close together.

Holding the Torch

A torch may be held in either one of two ways, depending on which is the more comfortable to you. When welding light-gauge metal, most operators prefer to grasp the handle of the blowpipe, with the hose over the outside of the wrist, in the same manner a pencil ordinarily is held. In the other grip, the torch is held like a hammer, with the fingers lightly curled underneath. In either case the torch should balance easily in the hand to avoid fatigue. See Figs. 17 and 18.

Position and Motion of the Torch

Hold the torch with the tip inclined sideways so that it points to the left at an angle of about 50 to 60 degrees to the surface of the

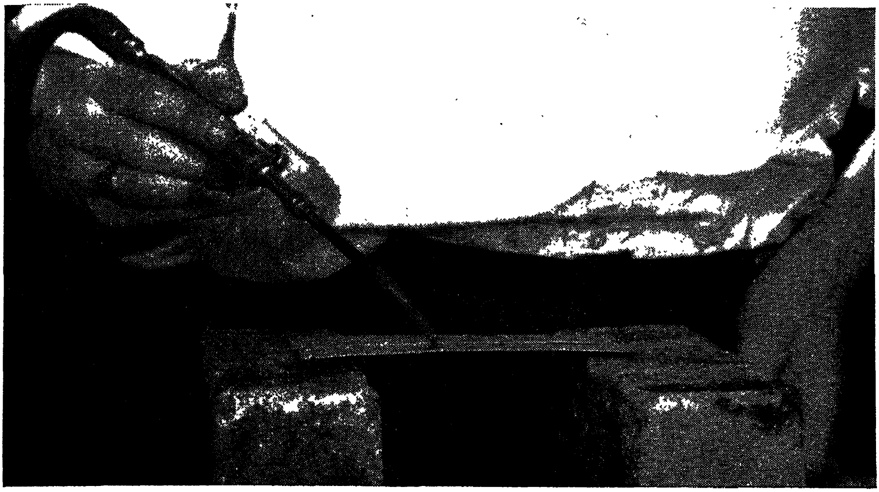

Fig. 17. Holding the Torch

plates. Bring the torch down until the white cone is approximately ⅛″ away from the metal. When the edges begin to melt, move the torch forward in a zigzag motion. See Fig. 18.

The welding should begin at the right end of the plate, gradually working to the left. Do not move the torch ahead of the puddle, but slowly work along the joint, giving the heat a chance to break down the edges of the plate. If the flame is moved forward too rapidly, the heat will not penetrate far enough and the metal will not melt properly. If the torch is kept in one position too long the flame will burn a hole through the metal. See Fig. 19, p. 37.

When the end of the joint is reached, the metal usually has a tendency to melt too rapidly, making it difficult to control the puddle. To prevent burning a hole through the plates, raise the torch slightly or flip the flame away momentarily to give the puddle a chance to solidify partly.

If the weld has been properly carried through, the surface will appear as shown in Fig. 19 C. The area melted by the flame should be of uniform width, with evenly spaced ripples along its entire length. This weld line should be slightly depressed below the rest of the surface of the metal. On the underside of the weld the same area should be slightly raised above the surface, showing that the penetration is complete.

The making of regularly spaced ripples depends entirely on a steady control of the torch movement. At first this may appear very difficult but after a little practice a uniform motion of the torch will be mastered. Watch closely the course of the flame to make certain that its travel along both edges of the plates is the same, keeping a molten puddle approximately ¼″ to ⅜″ in width. Advance this puddle about ¹⁄₁₆″ with each complete motion of the torch. Unless the molten puddle is kept active and flowing forward, correct fusion will not be achieved.

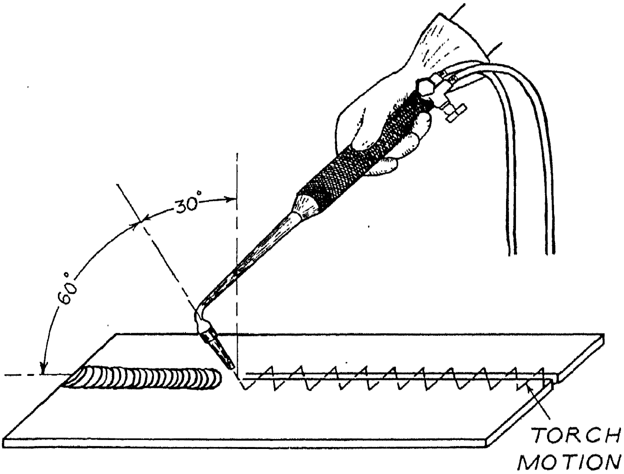

Fig. 18. Position and Motion of the Torch

Testing the Weld

The welded piece should next be tested. Pick the metal up with a pair of pliers, and cool it by submerging it in water. Then clamp the plate in a vise, with the weld parallel to the top of the jaws and the welded joint just above the top of the vise. Strike the top of the metal with a hammer, bending it against the weld. See Fig. 20. The

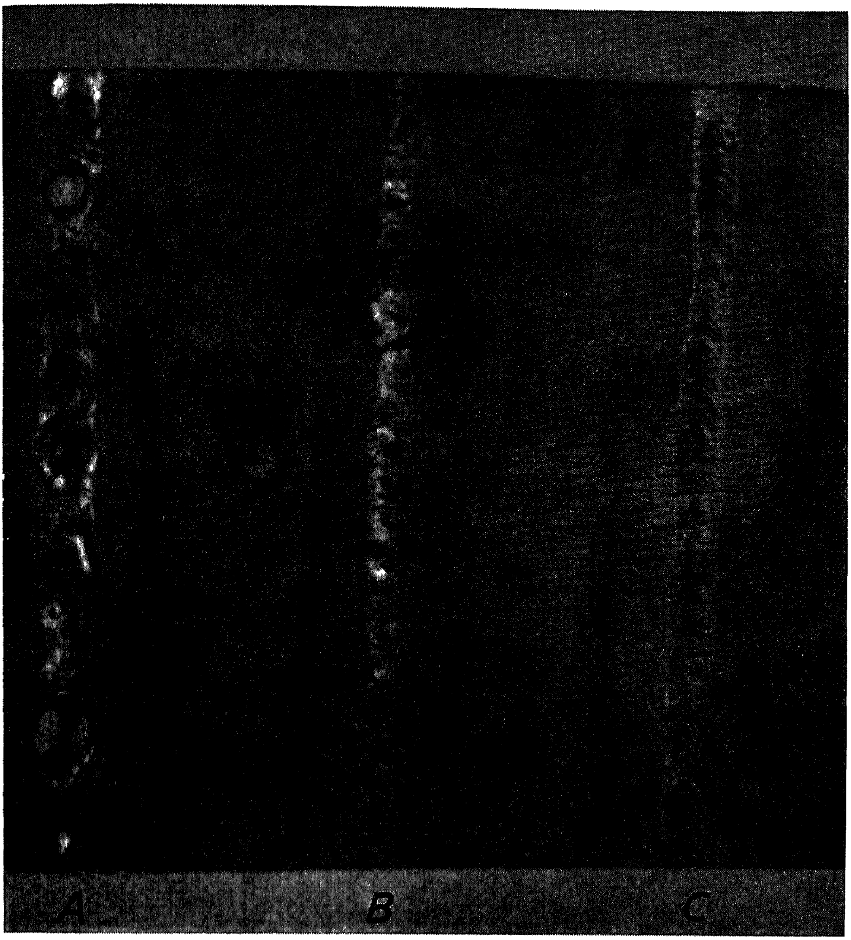

Fig. 19. Proper and Improper Fusion Welds. *A*—Metal Burnt from Flame Held too Long in One Place. *B*—Insufficient Penetration. *C*—Appearance of a Good Weld

test should always be made so that the underside or bottom of the weld is put in tension and the top in compression.

Hammer the metal until the joint has been bent to an angle of 90°. If the fusion has been correct no cracks should show between the two edges of the plates.

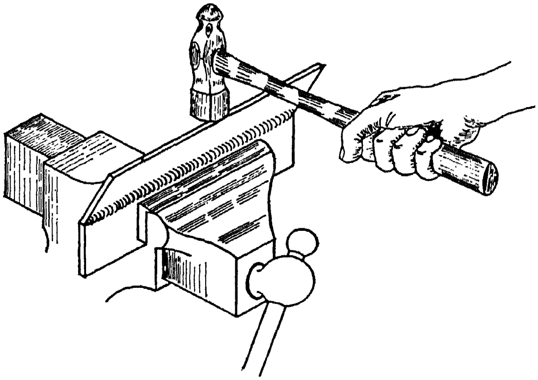

Fig. 20. Testing the Welded Joint

Common Defects

It is only natural to assume that the first few welds will break easily. Continue this exercise until you can make a straight, smooth weld that will not open when bent at right angles.

The following are some of the common defects that you may expect to find in your first few welds:

1. Uneven weld, caused by moving the torch too slowly or too rapidly

2. Holes in the joint, caused by holding the flame too long in one place

3. Imperfect fusion on the laps, caused by not heating the plates uniformly

4. A brittle weld, due to improper flame adjustment

5. Excessive metal hanging underneath the weld, showing too much penetration

6. Insufficient penetration, caused by moving the torch forward too rapidly

7. Hole in end of the joint, caused by not lifting the torch when the end of the weld was reached

QUESTIONS

1. What is meant by torch manipulation?
2. How should the torch be held in relation to the metal plates?
3. What is the proper movement of the torch during welding?
4. What governs the rate at which the flame should be moved forward?
5. What happens if the torch is moved forward too slowly?
6. Why should the torch be raised when it nears the end of the weld?
7. How should the welded joint be tested?
8. What are some of the common defects of a beginner's weld?
9. How should the top and bottom surfaces appear for a good fusion weld?
10. If the metal does not melt readily, what is the probable cause for it?

Unit 6

SAFETY IN WELDING

Safety in any line of shopwork is so important that too much emphasis can not be placed upon it. Safety involves human life, and endangering the life of someone through negligence or carelessness can never be tolerated. The risk to a welder is no greater than to the average individual working around mechanical equipment, provided the welding apparatus is used with a reasonable degree of intelligence.

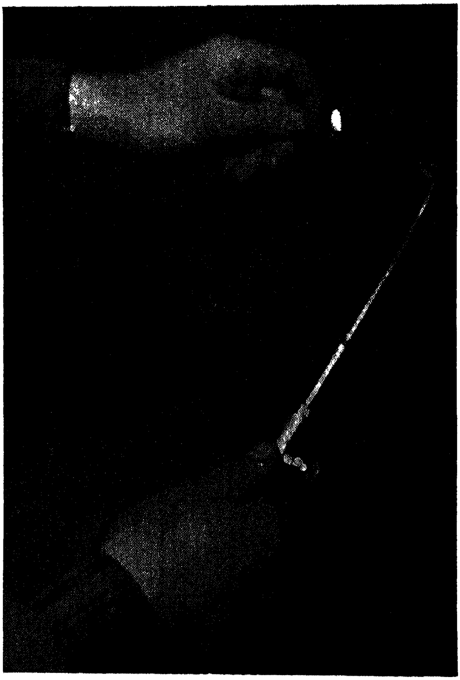

Fig. 21. DANGEROUS. Never Light a Torch with a Match

The beginner, being strange to the equipment, is generally quite cautious at the start, but, as he becomes somewhat proficient in handling a torch, he is inclined to be just a little overconfident in his ability, and disregards some of the safety rules. This is a matter each and everyone should carefully guard against because, as the old saying goes—it only has to happen once. A moment of carelessness and someone is injured. Although manufacturers have installed numerous safety devices in various parts of the welding apparatus, the operator must use a reasonable amount of care whenever the torch is in use

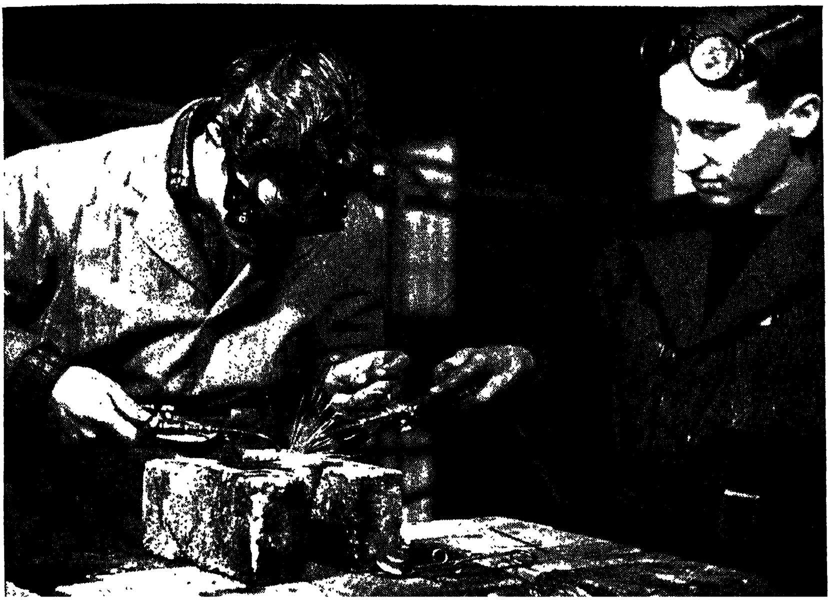

Fig. 22. DANGEROUS. Never "Borrow a Light" from your Neighbor's Torch

The safety rules listed in this Unit should be studied and strictly observed. If this is done there will be very little chance for any serious accident.

Proper Clothing

Every welder should wear an apron, shop coat, or coveralls. Sparks will invariably shoot away from the molten metal, and, without some suitable covering, numerous holes will be burned in the operator's good clothing. Under no circumstances should a sweater be worn while welding. A small spark falling on this garment will very likely burst into a rapid-spreading flame that may have dire consequences. Skull caps of some kind are also desirable to prevent any hot metal particles from falling on the hair.

The welder should wear a pair of lightweight gloves. These will protect the hands not only from the heat given off by the torch but prevent any chance of burning the fingers while handling the filler rod or metal plates. Frequently the hot end of a rod or a piece of metal, which has been momentarily laid aside to cool, is picked up by mistake, and without gloves serious burns are apt to result.

Lighting the Torch

Never use a match to light a torch. See Fig. 21. This procedure necessitates bringing the fingers too close to the tip and the sudden ignition of the acetylene is very apt to burn the fingers. A spark-lighter or stationary pilot flame should be available for this purpose and this must always be used.

When igniting a torch, keep the tip facing downward and preferably against the bench top. Lighting the torch while it is facing outward or upward may result in burning someone nearby as the ignited flame spurts out. If other people are welding around the

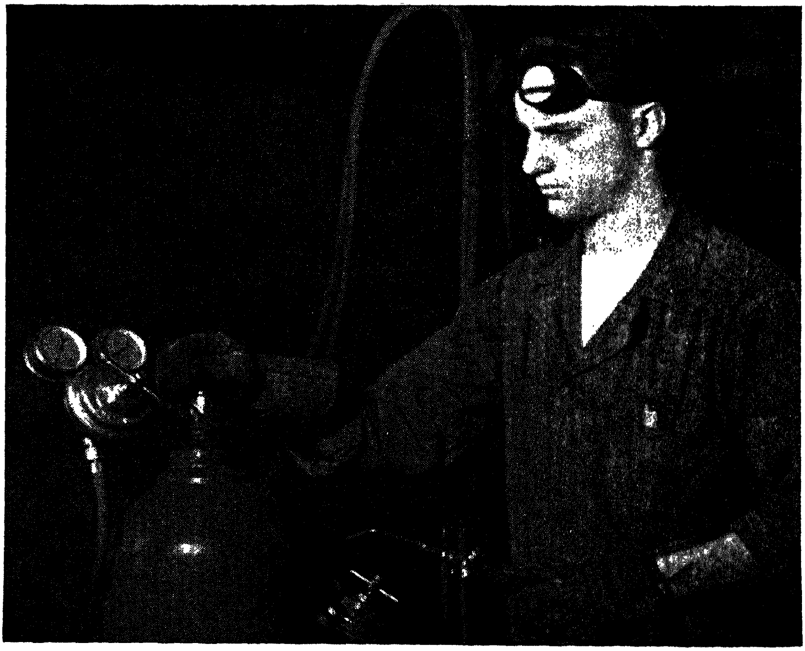

Fig. 23. Correct Position for Opening a Cylinder Valve

same area never reach over to the other fellow for a light. See Fig. 22. He may be welding, and bringing your torch near his will not only disturb his work but more than likely burn his face or hands.

No attempt should ever be made to relight a torch from the hot metal when welding in an enclosed box, tank, drum, or other small cavity. There may be just enough unburned gas in this confined space to cause an explosion as the acetylene from the tip comes in contact with the hot metal. Instead, move the torch into the open, relight it in the usual manner, and make the necessary adjustments before resuming the weld. Before attempting unusual welds in confined areas, consult your instructor on the best method.

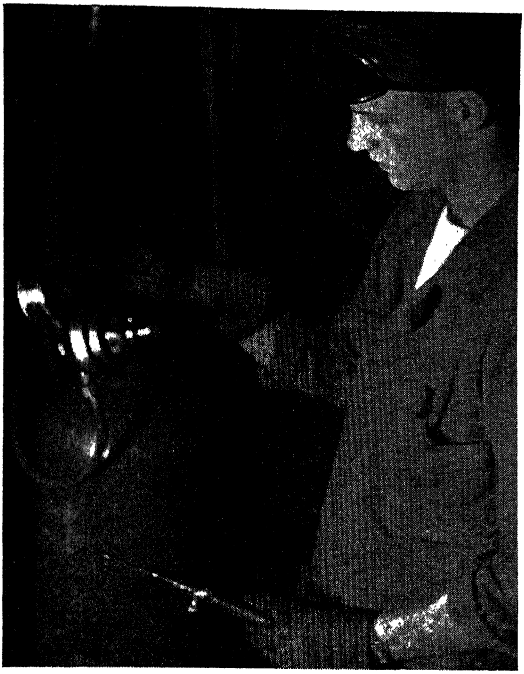

Fig. 24. DANGEROUS. Incorrect Position for Opening a Cylinder Valve

Opening the Cylinder Valves

Do not stand too close to a regulator when opening the cylinder valve. See Fig. 24. A defect in the regulator may cause the gas to blow through, shattering the glass and blowing it in your face. Make it a practice to stand to one side of the regulator as in Fig. 23, and turn the cylinder valve slowly. Remember, oxygen and acetylene are charged in the tanks under a high pressure and if the gas is permitted to come against the regulator suddenly, it is apt to cause some damage to the equipment. Open the acetylene-cylinder valve approximately one complete turn and the oxygen valve all the way.

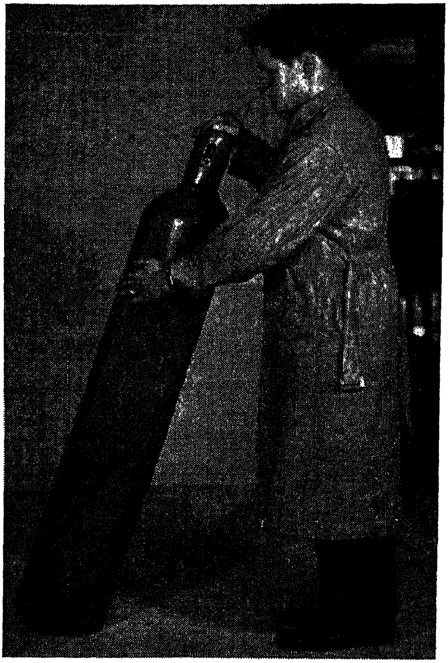

Fig. 25. Correct Way to Move a Cylinder. The Rolling Motion Not Only Is Less Dangerous but an Easy Way to Handle a Heavy Cylinder.

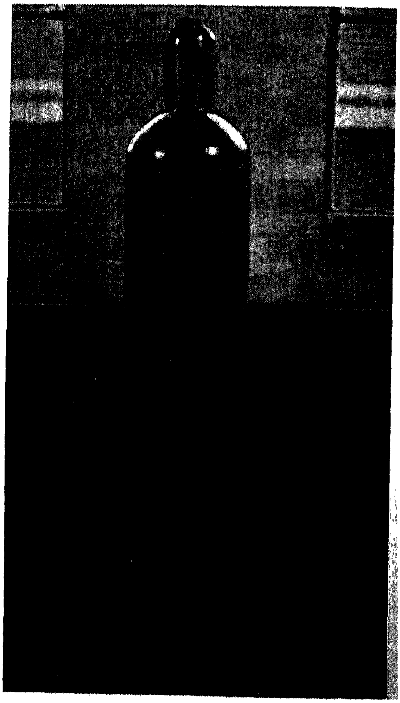

Fig. 26. DANGEROUS. Heat from a Radiator Expands Gas in a Cylinder to Explosive Pressure.

Handling a Cylinder

When a cylinder must be moved, it should be rotated on its bottom edge. Place the palm of one hand over the protection cap and tilt the cylinder toward you. Start the tank rolling by pushing it with the other hand. See Fig. 25.

A cylinder should never be transported by dragging, sliding, or rolling it on its side. Avoid striking the tank against any object that might create a spark. There may be just enough gas escaping to cause an explosion.

General Precautions

1. Never allow grease or oil to come in contact with cylinder valves, torches, or regulators. Although oxygen is in itself noninflammable, if it is allowed to come in contact with any inflammable material it will quickly aid combustion.

2. Avoid exposing cylinders to furnace heat, radiators, open fire, or sparks from the torch. See Fig. 26.

3. Under no circumstances should acetylene be used beyond a 15-pound pressure. Acetylene in excess of this pressure is likely to explode. For all welding purposes, a pressure of 15 pounds or less is sufficient.

4. Never weld a container that has been used for gasoline, oil, etc., unless it has been thoroughly steamed. Even then, if possible, it should be partly filled with water.

5. Never weld without proper goggles. Your eyes are valuable! It is extremely foolish to take the chance of handling a torch without suitable eye protection.

6. If cylinders have to be moved, be sure that the cylinder valves are shut off.

7. Whenever a leak is noticed, shut down the cylinder valves immediately and make the necessary repairs before resuming the welding.

8. If welding or cutting is to be done in places having wooden floors be sure to cover the floor with metal or other suitable, noncombustible material where sparks or hot metal are liable to fall.

9. Never use oxygen as a substitute for compressed air.

10. Never hang a lighted torch over a cylinder or regulator.

11. Never weld a closed container, tank, etc., until precautions have been taken to properly vent it. A small opening should be drilled into it; otherwise, it is apt to explode.

12. Make sure that the space between the work bench and cylinders is clear so that the cylinder valves can be quickly reached in case of need.

QUESTIONS

1. Why is safety in a welding shop very important?
2. Why should a welder wear suitable clothing when welding?
3. Why is it poor practice to light a torch with a match?
4. Why should a torch never be relighted from the hot metal when welding inside a container?
5. Where should one stand while opening a cylinder valve? Why?
6. What danger is there in dragging a cylinder?
7. What effect does grease or oil have on an oxygen cylinder valve?
8. Why should a cylinder never be placed near any source of excessive heat?
9. Why should acetylene never be used beyond a 15-pound pressure?
10. Why is it dangerous to weld a container which has held gasoline or oil?

PREVENTING WELDING AND CUTTING FIRES *

Oxy-Acetylene welding and cutting are two of industry's most useful and indispensable tools. With the responsibility of training workmen to employ these tools to the best advantage, there is the added need for seeing that they are used safely. Just as with any process involving open flames and sparks, there is a particular responsibility to see that fires are kept from starting, and that fires which may start despite all precautions are quickly put out.

There are some places in nearly every plant or shop where it is never permissible to do any sort of work. which makes flame, heat, or sparks. For instance, extreme care is always necessary near explosive gases or inflammable liquids; and such things as smoking, blowtorches, open lights, sparking tools, and every other possible source of ignition must be prohibited. But welding and cutting can be done in most other locations with complete safety if certain reasonable precautions are taken. When a welding or cutting operation is a part of a production process, and arrangements can be made for safeguarding surroundings and the material on which the work is being done, it is rare indeed that a fire occurs.

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Ways a Fire May Start

Knowing the ways that fires may start is an important step in learning how to prevent them.

Heat sufficient to start fires may come from the oxy-acetylene flame itself; from the metals being welded or cut; from molten slag or metal that blows or drips from the cut; and from sparks which fly from the work.

Some materials will catch fire from these sources of heat more quickly than others. Inflammable gases and liquids, with air or oxygen present, are examples of materials that would flare up at once. Oily waste and rags, and light materials such as burlap, excelsior, cartons, straw, or waste paper catch fire less easily but burn vigorously once started.

Wooden flooring, timber structures, scrap lumber, wood chips, tarpaulins, rags, and similar materials are less apt to catch fire than the others mentioned. Yet this is all the more reason why special precautions must be taken with these combustible materials. For fires started in them may only smolder at first, and then may flare up sometime later—due possibly to a gust of air or a natural draft created by the smoldering heat.

The Oxy-Acetylene Flame

The oxy-acetylene flame is itself rarely the cause of a fire—probably because it is so evident to anyone using it that the flame and combustible materials should be kept apart.

Metal Welded or Cut

Heat from the metal being welded or cut may sometimes be the cause of fires, if hot pieces of metal are allowed to touch materials that burn easily. This is more apt to happen in the case of cutting steel and iron, because small pieces are often cut away from larger sections and are allowed to drop onto the floor or ground. The smaller or narrower the piece cut away, the more heat it will have absorbed, and the more likely it is, therefore, to set fire to burnable materials.

Pieces of iron or steel which have been heated to a bright red may retain enough heat to start fires for 5 to 15 seconds or even much longer under some conditions. Even though the piece may be at a black heat in daylight, it can scorch such things as wood or paper and a fire may start if there is enough draft.

Cutting Slag

The molten slag that drips or blows from a cut is generally more apt to set fire to nearby combustible materials than pieces of red-hot metal. This is because the slag is at the temperature of molten steel when it falls, and therefore it stays hot longer. However, when the slag drops from a height of about 15 feet or more, it tends to scatter and cool more quickly than would a small piece of red-hot steel dropped from the same height.

Everyone knows that molten slag is hot, and it has always been the practice to catch slag in a pan of sand or pail of water, to keep wooden floors from scorching or burning, or to prevent concrete floors from spalling.

Sparks

Because they will often fly in so many directions at once, and because they sometimes travel for a considerable distance, sparks from cutting or welding must be watched closest of all to make sure they do not set fires. Sparks really are little balls of glowing metal oxides, and some of the larger ones may retain enough heat to start fires for several seconds after landing.

Sparks which fly from welding work do not usually travel far unless there is wind or a strong draft. They are harmless enough if combustible materials are not too close to the work.

Cutting produces by far the heavier shower of sparks. The cutting sparks travel the farthest and stay hot longest because of their larger size. Much greater precaution must therefore be taken when using the cutting torch.

Heavy sparks from cutting work may sometimes travel as far as 25 or 30 feet away from the point of cutting. They can readily set fire to light materials such as excelsior, paper, or oily rags. It goes without saying that if sparks should fall into containers holding inflammable liquids, quick and dangerous fires would be the result. Severe fires have been started by sparks falling into unprotected, oil-soaked engine pits.

But it is most important to realize that sparks which fly away some distance or roll along the floor may sometimes cause smoldering fires if they come into contact with materials that do not ignite readily. Those who have done welding or cutting know how easy it is for cotton gloves to start smoldering due to sparks flying from the work. In the same way, sparks which fall on other things that will burn, even though some distance away from the welding or cutting, can also cause smoldering fires.

Smoldering fires may start by sparks getting into cracks in floors and woodwork, or by sparks lighting on materials such as rags, tarpaulins, paper wrappings, wood chips, scrap lumber, and worn cushion pads. Sometimes these fires go out, but at other times they continue to smolder and may show up as long as a half hour later.

Location of Work

Every foreman in charge of welding or cutting knows that when this work is part of a regular production or repair operation, and is carried on in the same location time after time, there is small likelihood of fires being started. There are a number of reasons for this. In the first place, fire hazards are usually eliminated before welding or cutting equipment is installed. Any hazards that may be overlooked at first are generally taken care of after a short time, and the welding or cutting work is then well safeguarded.

On the other hand, welding or cutting work done with portable equipment in temporary locations is much more apt to cause fires, unless suitable precautions are taken. For one thing, the equipment is used in a wide variety of places—quite often places which cannot be made as proof against fire as a welding shop. Sometimes the fire hazards are not out in plain sight and are known only by the local foreman or superintendent. Often an outside contractor brings in welding and cutting equipment, and his men may hesitate to ask for the necessary assistance in preventing fires. Demolition work presents a serious problem of fire prevention due to the general disorder and litter common on such jobs.

The facts are that of all fires caused by welding and cutting work, about 80 per cent are caused by cutting in some place other than a permanent, safeguarded location. This will explain why the following recommendations on preventing fires are chiefly concerned with sparks and slag from cutting work.

The facts, too, are that welding and cutting fires are preventable. Companies that encourage their foremen to enforce these recommendations have as low a fire-loss record with their portable equipment as with their welding and cutting equipment operated in a permanent location.

Preventing Fires

The safest and surest rules to follow in preventing fires are to:

1. *Keep flames, sparks, molten slag and hot metal from coming in contact with materials that will burn.*

Take no chances. Fires can get the best of you at times even if you are prepared to put them out.

It is particularly important that this rule be observed in and around plants and buildings where sparks or flames from any source would be very hazardous. Such would be the case in rooms containing combustible gas or liquids, or any material that easily catches fire. Smoking, open lights, and any tool or piece of equipment which would cause a spark or flame are always barred from such locations. Therefore—

2. *Never use cutting or welding torches where sparks or an open flame of any kind would be a hazard.*

It is not safe to use cutting or welding equipment near rooms containing inflammable materials unless there is absolutely no chance of sparks passing through cracks or holes in walls or floors, through open or broken windows, or open doorways. There is also always the possibility that inflammable vapors may escape from such rooms through doors or other openings, making it doubly necessary to keep sparks and flames away. Therefore—

3. *Before you cut or weld in a new location for the first time, always check with the nearest foreman or superintendent in authority.*

He may know of some serious fire hazard that you might fail to guard against.

When it is possible to do so—

4. *Take cutting or welding work which can be moved, to a location where there will be no possibility of setting fires.*

This must always be done when the metal to be welded or cut is in a place where open flames are barred. This practice may also be sensible in many other locations even if open flames are permitted.

If the work cannot be moved to a safe location—

5. *Materials that burn easily should if possible be moved a safe distance.*

If cutting is to be done, this distance may be 30 to 40 feet or more. Floors should be swept clean before the torch is lighted.

If it is not possible to move material that will burn to a safe distance from the work; or if sparks might lodge in wooden parts of the building, or drop through holes or cracks to the floor below—

6. *Use sheet-metal guards, asbestos paper or curtains, or similar protection to keep sparks close in to the work you are doing.*

Make sure that the guards are large enough and tight so that they do not permit sparks to roll underneath or slide through openings. Curtains should be weighted down against the floor or ground so sparks cannot possibly get underneath. For weights, use such things as angle iron, pipe, bricks, or sand. Use only fire-resisting guards. Do not use tarpaulins for shielding sparks, since they may catch fire. Have someone stand by to watch the sparks so he can give warning if they begin to get beyond the protective guards. It is not reasonable to expect whoever is welding or cutting to watch the sparks, as his attention is on the work. In addition, the sparks cannot always be seen easily through his goggles.

If welding or cutting is to be done over a wooden floor—

7. *Sweep wooden floors clean and wet them down before starting work.*

Provide a bucket or pan containing water or sand to catch the dripping slag from any cutting that is done. Keep all sparks close in to the work as recommended in the paragraph above.

Before starting to cut off a piece of steel or iron, make sure it will not drop where there is any possibility of starting a fire. This is especially important when working in a high place where sparks or slag might be less apt to cause a fire down below than would a small piece of red-hot steel. Pieces can be kept from falling by welding a rod or bar to the piece, and having a helper hold the rod or bar while the cut is made. Or the same thing can be accomplished by tying a chain or rope to the piece.

When welding very close to wooden construction, such as wooden beams, partitions, flooring, or scaffolding, always use sheet metal guards or asbestos to protect the wood from the direct heat of the flame. Of course, protective guards should also be used to confine the sparks.

Oxy-Acetylene Apparatus

Don't run the risk of causing a fire with the welding or cutting apparatus.

1. *Always guard the oxygen and acetylene hose from chance of injury on the job.*

Acetylene escaping from a broken hose line might easily catch fire and then transmit fire to cylinders or other materials nearby. Do not use any oxyacetylene equipment that is in need of repair. Make sure that torches, regulators, and hose are always in good, safe condition and that all connections are tight. Use soapy water to test for leaky connections.

2. *Use the correct oxygen pressure when cutting.*

An oxygen pressure greater than necessary will only cause extra sparks and increase the slag flow, to say nothing of increasing the oxygen expense.

Since oxygen and acetylene released from cylinders would make any fire which might break out burn all the harder—

3. *Store extra cylinders away from working areas.*

Keep only enough cylinders near the work to insure an adequate supply of gases for the job at hand.

Be Prepared to Put out Fires

When torches are to be used near wooden construction or materials that will burn, take every precaution to prevent fires, but always:

1. *Be ready to put out any fire promptly with fire extinguishers, pails of water, water hose or sand.*

Have a helper, or one or more extra men if necessary, on hand ready to extinguish a fire.

If the place in which cutting is to be done is provided with sprinklers—

2. *Maintain sprinkler protection without fail while cutting or welding is being done.*

It is of special importance to make sure sprinklers are working during extensive repairs or building changes. If sprinklers must be shut down for a time, have this done, if possible, when welding or cutting work is not in progress.

When torches have been used in locations where sparks may have lodged in wooden structures or in materials that will burn, and may cause smoldering fires—

3. *Keep a man at the scene of the work for at least half an hour after the job is through.*

Have him look carefully for smoke or fire before leaving. Don't forget that heavy, cutting sparks sometimes fly 25 to 30 feet or more and hold their heat for several seconds after landing.

Unit 7

LAYING A BEAD WITH WELDING ROD

ON SOME TYPES of joints it is possible to weld the two pieces of metal without adding a filler rod. In most instances the use of a filler rod is advisable because it builds up the weld, thereby adding strength to the joint. The strength of a weld depends largely on the skill with which the rod is blended, or interfused, with the edges of the base metal.

The material in this lesson will help you to determine the kind of rod to use and how it should be worked in with the molten edges of the parent metal.

Selection of Welding Rod

A welded joint should always possess as much strength as the base metal itself. If this is to be accomplished it is necessary to employ a welding rod that has the same chemical composition as the base metal. It is a mistake to attempt to use just any kind of wire, because an inferior rod contains so many impurities that it is extremely difficult to use and makes a weld that is weak and brittle. A good welding rod will flow smoothly and readily unite with the base metal without any excessive amount of sparking. A rod of poor weldability will spark profusely, flow irregularly, and leave a rough surface filled with punctures like pinholes.

Filler rods come in a variety of sizes ranging from 1/16″ to 3/8″ in diameter. The size of rod to use will depend largely upon the thickness of the metal. The general rule is to employ a rod whose diameter equals the thickness of the base metal. In other words, if 1/16″ metal is to be welded, a 1/16″ diameter rod should be used, etc.

A great many different kinds of rods are available for welding a variety of metals. For example, a mild-steel rod is used for welding mild steel, cast-iron rod for cast iron, nickel rod for nickel steel, bronze rod for bronzing malleable cast iron and other dissimilar metals, aluminum rod for aluminum welding, copper rod for copper products, etc.

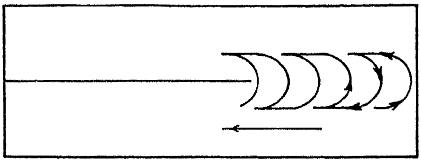


Fig. 27. Semicircular Motion of the Torch

Manipulation of the Welding Rod

The rod should be held at approximately the same angle as the torch but slanting in the opposite direction. It is advisable to bend the end of the rod at right angles, since this permits your holdng the rod away from a direct line to the heat of the flame. See Fig. 28.

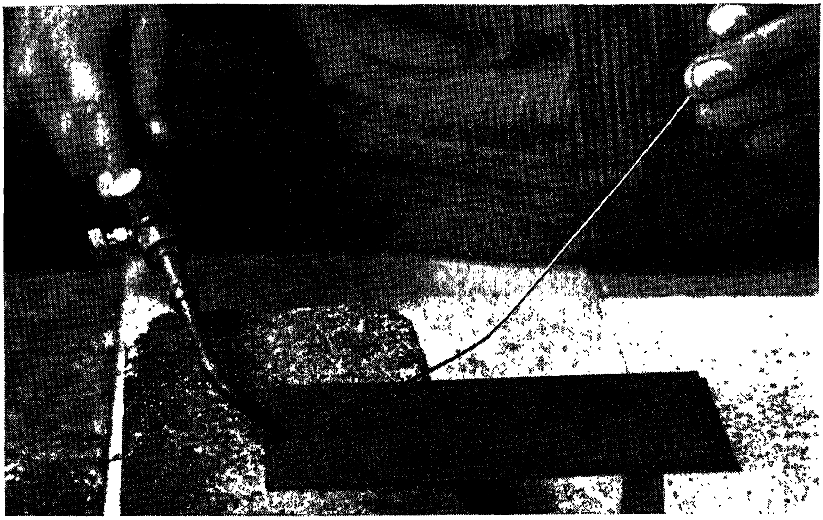


Fig. 28. Position for Holding a Rod

The general method in manipulating the filler rod is to melt a small pool of the base metal and then insert the tip of the rod in this pool. It can be seen from this that to secure perfect fusion the correct diameter for the rod is important. If the rod is too large the heat of the pool will be insufficient to melt the rod, and if the rod is too small the heat cannot be absorbed by the rod, with the result that a hole is burned in the plate.

As the rod melts in the pool, advance the torch forward. Care must be exercised to concentrate the flame on the base metal and not on the rod. Avoid holding the rod too high above the pool, so as to prevent the molten metal of the rod from falling drop by drop onto the plates. This must be learned by practice.

Practice Weld

The difficulty with most beginners is in timing the dipping of the rod in the molten pool. To overcome this fault, practice laying a straight bead with a filler rod on a piece of scrap plate. Do this without attempting to weld two pieces of metal. Make sure the base metal is flowing before inserting the rod, and work from right to left. Vary the motion of the torch from the previously described zigzag movement to more of a semicircular motion. See Fig. 27. In carrying out this semicircular movement, the bottom of the arc should be toward the metal that is deposited.

Continue to practice melting welding rod on a piece of metal until you are able to lay a straight, ripple bead 4 to 5 inches in length.

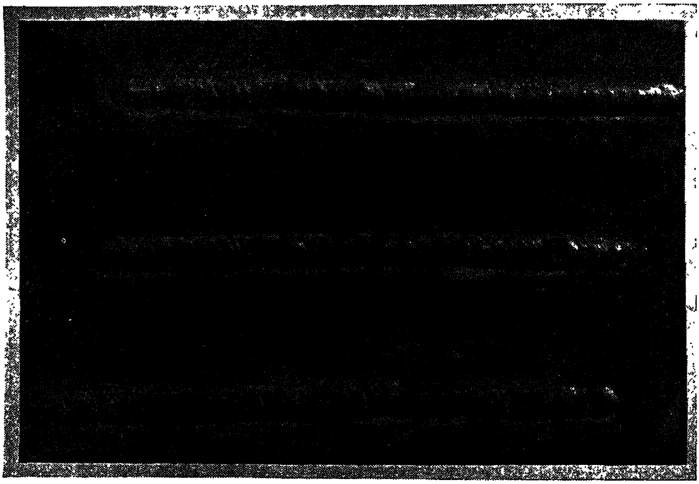


Fig. 29. Straight Beads Laid with a Rod

QUESTIONS

1. Why is a filler rod used in welding?
2. How can you determine whether or not a rod is good or poor?
3. What determines the size of the rod that should be used?
4. Name a few kinds of welding rods and state the kind of work for which each is best suited.
5. Why should poor rods never be used?
6. How should the rod be fused with the base metal?
7. What happens if the rod is too large for the size of metal that is being welded?
8. How should the torch be manipulated when a filler rod is used?

Unit 8

WELDING PLATES WITH FILLER ROD

IN THIS LESSON you are to practice welding two pieces of metal, using a filler rod. Do not attempt to do this exercise until you have acquired enough skill in manipulating the rod to prevent it from continually sticking to the metal.

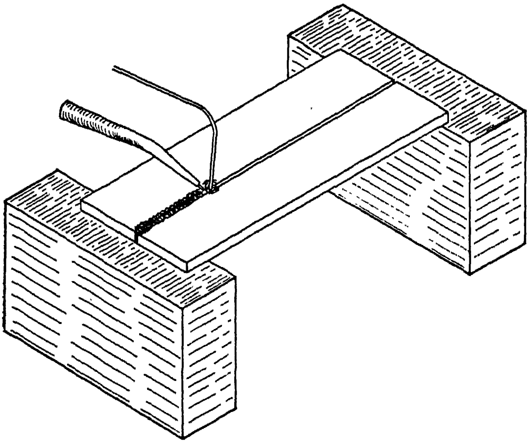


Fig. 30. Welding with Rod

Practice Weld

Secure two pieces of 1⁄16″ or 1⁄8″ metal 4″ to 5″ in length. Set them on two firebricks as described in the first welding exercise.

However, in this case do not bring the edges close together, but allow a gap of about 1⁄16″ at the starting end of the joint and approximately 1⁄8″ at the other. The purpose of this space is to allow for expansion of the metal, otherwise the edges will overlap before the weld is completed.

Select the proper-sized welding rod and tack the plates at the left end. Begin welding at the right end, using a semicircular movement. See Fig. 30. Work the torch slowly to give the heat a chance to penetrate the joint, and add sufficient filler rod to build up the weld about $\frac{1}{16}''$ above the surface. Be sure the puddle is large enough and the metal flowing freely before you dip in the rod. The distance the flame should travel across the joint depends largely on the thickness of the metal. The heavier the plate the wider the arc should be. As the end of the joint is reached, increase the forward speed of the torch a little and raise it at the same time. This will prevent overheating the metal and breaking the edges down too quickly.

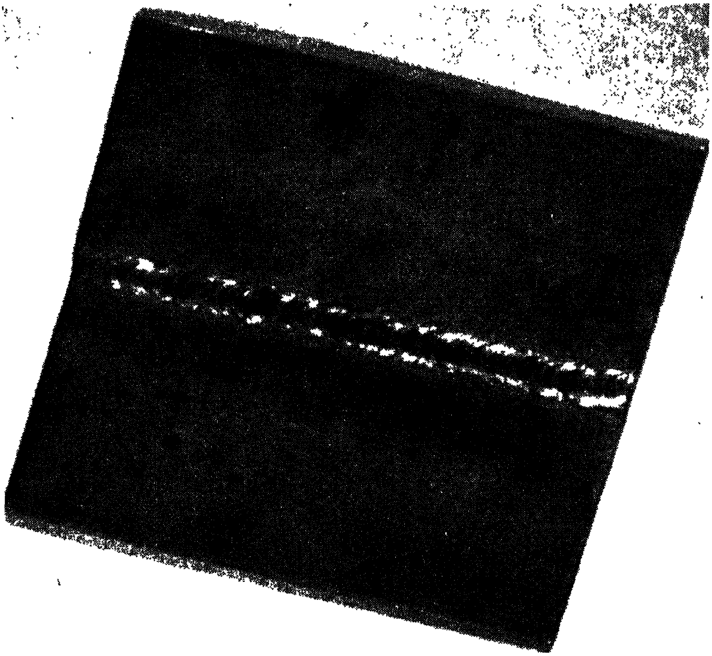


Fig. 31. A Good Ripple Weld

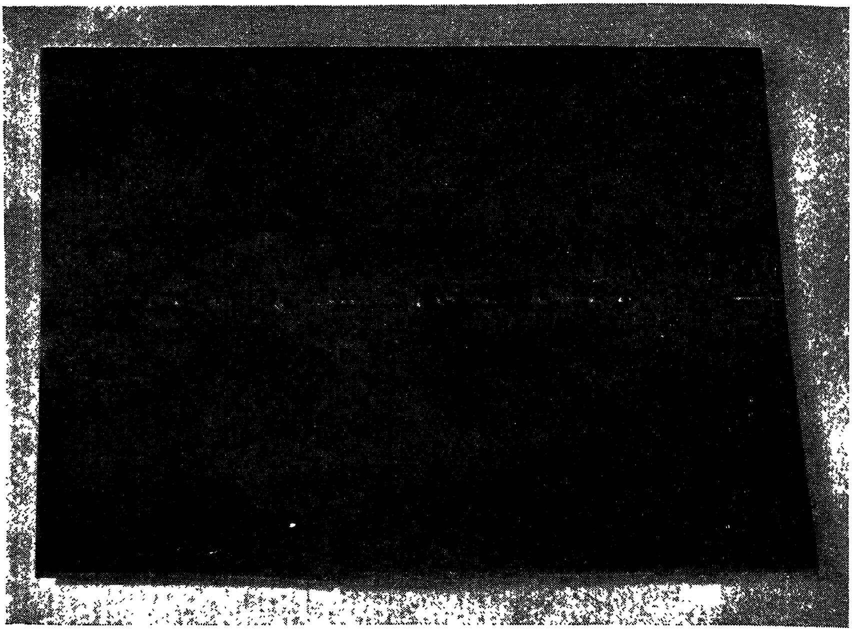


Fig. 32. Correct Penetration

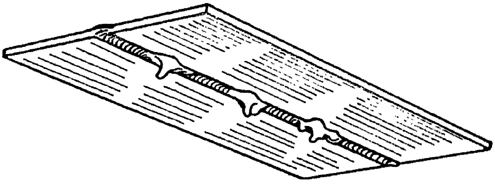


Fig. 33. Weld Showing Uneven Penetration

Testing the Weld

If an excess amount of metal shows on the underside, it is an indication of too much penetration, usually caused by moving the torch too slowly. On the next try, speed up the forward motion of the torch a little.

If the original underside edges show, it probably means that penetration has not been complete, caused by moving the torch too rapidly.

Now test the joint by placing it in a vise and bending the plate against the weld. A good joint will bend to a 90° and even a 180° angle without showing any signs of failure. If the edges open up it indicates improper fusion.

Very often a joint appears to have correct peneration and still cracks open when tested. This may be caused by a number of reasons, such as:

1. Improper space allowances between the edges of the plates.

2. Filling the space between the metal plates with molten rod without sufficiently breaking down the edges of the plates to insure a good bond between the parent metal and rod.

3. Holding the torch too flat, causing the molten puddle to lap over an area that has not been properly melted.

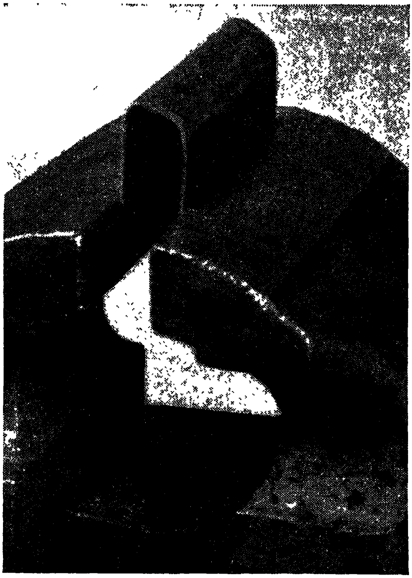


Fig. 34. Correct Bend Test

QUESTIONS

1. Why it is necessary to be able to manipulate the rod before attempting to weld two pieces of metal?

2. What size tip should you use for welding ⅛″ metal?

3. What working pressure is required for this exercise?

4. Why should the weld be built up slightly above the surface?

5. Why should the edges of the plates to be welded be slightly apart?

6. Why should the plate be tacked on one end before welding?

7. What is the cause of insufficient penetration on a welded joint?

8. How can you remedy too much penetration on a joint?

9. What effect will burning the metal have on the resulting weld?

10. How can a good weld be determined?

Unit 9

CARE OF WELDING EQUIPMENT

One of the first requisites of a good welder is to be able to take care of his equipment. Skill alone is not sufficient to produce satisfactory work. The equipment with which this work is done must be in the best of condition at all times, and the only way it can be kept working properly is through careful and thoughtful usage. If the welding equipment is functioning properly, less time is lost on the job and better results are accomplished with the least effort.

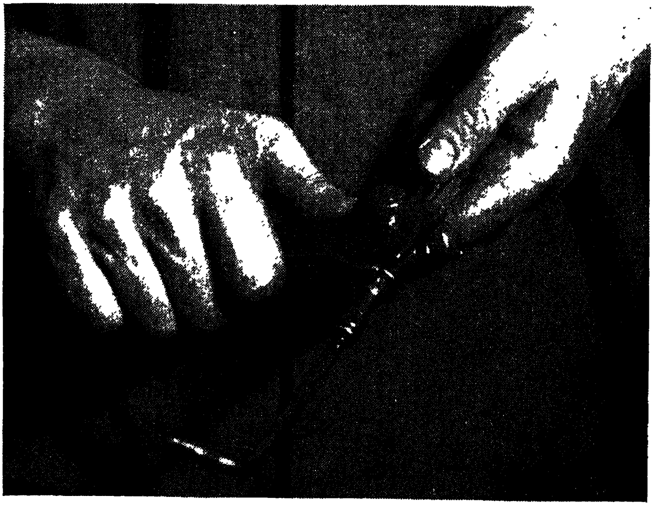


Fig. 35. Adjusting Needle-Valve Nut

Care of the Torch

The construction of most torches is quite sturdy, but they are never so strongly built that they can be used as hammers.

When the welding is completed, the torch should be suspended in such a manner that it will not fall to the floor. The needle valves especially are somewhat delicate, and care must be taken never to drop the torch so that they will strike some hard object. Occasionally the needle valves will turn too freely, making it difficult to secure and keep the adjustment for the proper mixture. When this occurs, give the safety-lock nuts on the stem of the needle valves a slight turn with a wrench. See Fig. 35.

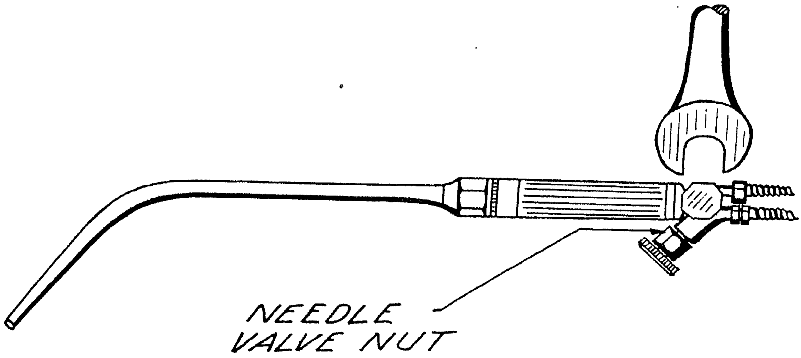


Fig. 36. Tighten Needle-Valve Lock Nut with Tight-fitting Wrench

Care of Welding Tips

At some time or other it will be necessary for the welder to remove a tip. Changing a tip should always be done with a wrench especially made for this purpose. See Fig. 37. Under no condition should pliers be used to remove a welding tip. See Fig. 38. Pliers quickly ruin the nut on the tip, rendering it practically useless.

A tip should never be inserted while the torch is hot. Heat naturally expands the threads, causing the tip to "freeze" onto the torch after it has cooled. Attempting to force a tip loose from the torch later may result in breaking off the threaded section, thus ruining the tip and adding the task of removing the broken section from the opening of the torch.

A tip must be kept clean at all times to produce a satisfactory weld. Frequent use of the torch will cause a formation of carbon in the passage of the tip; this carbon may be removed by inserting a copper or brass wire through the opening. Hard, steel wire should never be employed, as it will scratch the surface of the passage.

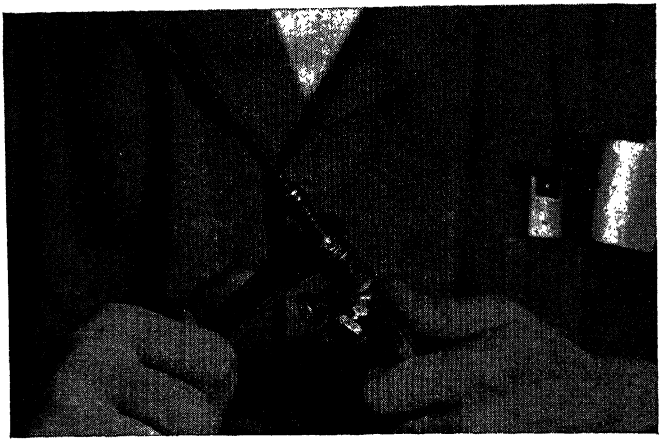


Fig. 37. Change Tip with Proper Tip Wrench

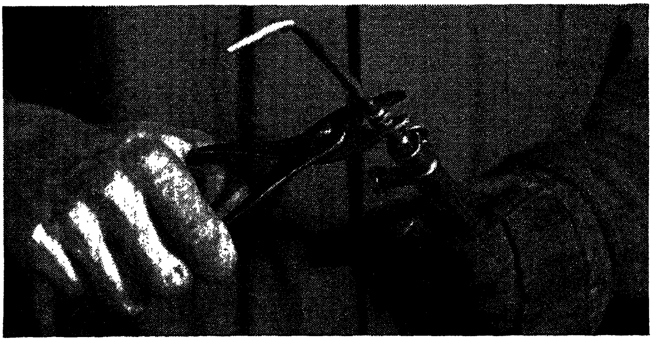


Fig. 38. Never Use Pliers

Brushing the end of the tip with a fine grade of sandpaper is also advisable at times. Periodically, a proper-sized tip drill should be used to clean out the passage of the tip.

Care must be exercised in screwing a tip into the torch to prevent stripping of the screw threads. Work the tip in by hand, using a wrench to tighten the last thread. Never draw the tip up too tightly, but just enough to prevent the gas from leaking.

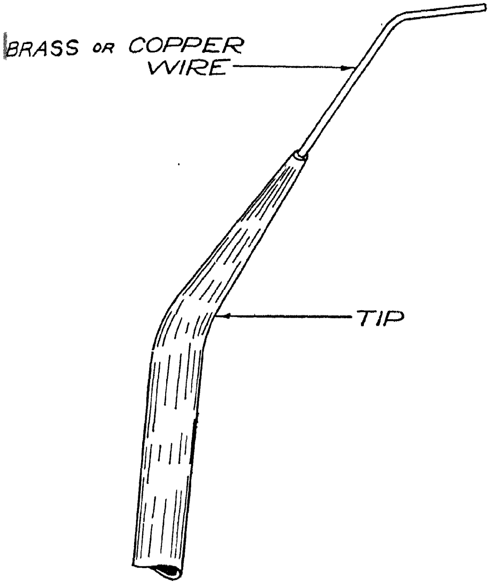


Fig. 39. Cleaning Tip with Brass Rod

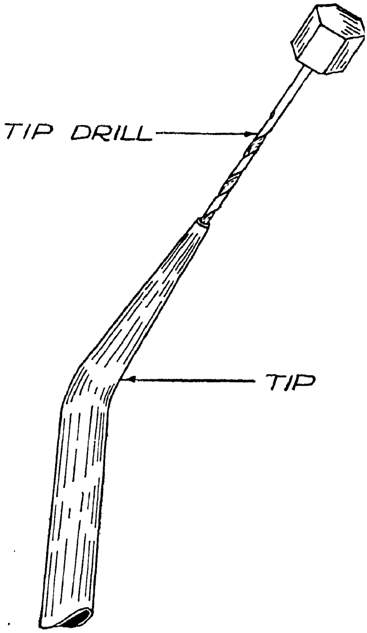


Fig. 40. Drilling out Tip

Care of Regulators

Regulators are sensitive instruments and must at all times be regarded as such. It takes only a slight jar to put a regulator out of commission. Be extremely careful in handling the regulator while removing it from the cylinder. Never allow a regulator to remain on a bench top or floor for any length of time, as someone may come along and carelessly move it, which may result in breaking the glass on the gauges or damaging the regulator itself.

Always check the adjusting screw before the cylinder valve is turned on, and release this screw when the welding has been completed.

Care of Welding Hose

The acetylene and oxygen hose is an important part of the welding equipment. First of all, as was previously mentioned, all the connections on the hose must be perfectly tight. These connections should be tightened with close-fitting wrenches to prevent damaging the nuts.

Avoid dragging the hose around on a greasy floor, since grease or oil eventually will soak into it. Be careful in pulling the hose around sharp objects and, especially, over hot metal. Prevent anyone from stepping or dropping anything on the hose. When the welding has been completed, roll up the hose and suspend it in such a manner that it will not drop to the floor.

Care of Cylinders

Although the cylinders belong to the manufacturer supplying the gas, they should be given as much consideration as the rest of the equipment. Negligence in the use of cylinders involves a certain degree of danger to the user of the welding equipment. Damage to the screw threads on the cylinder valves may ruin the nut on the regulators.

Avoid exposing the cylinders to any intense heat, oil, grease, etc., and when they are not in use keep the protector caps over the valves. Store empty cylinders in such a way that they will not be knocked down.

Care of Welding Goggles

If your eyes are to be protected from injury, the goggles must be kept in good condition at all times. The colored lenses should be covered with a clear-glass lense. Otherwise the colored lenses will soon become so pitted as to make them almost useless. It is by far cheaper to replace the clear-glass protectors than the expensive, colored lenses.

Care of the Sparklighter

A sparklighter should be used only for lighting a torch. The flint which furnishes the spark for ignition wears quickly if needlessly used. Place the lighter in a convenient position on the welding bench so it will be readily and quickly accessible when desired.

QUESTIONS

1. Why should a welder learn to take proper care of his equipment?

2. Why is it necessary that a close-fitting wrench be used in removing a tip?

3. What is the objection to using pliers for removing welding tips?

4. What care should be given the needle valves?

5. What is a tip drill, and when and why should it be used?

6. What precautions should be observed in the handling of a pressure regulator?

7. Why should the hose never be pulled around sharp corners?

8. Why should plain-glass protectors be used over the colored lenses?

Unit 10

WELDING A LAP JOINT

A WELDER is often required to make a lap joint, which necessitates welding the thin edge of a piece of metal to the flat surface of another plate. In practice-welding this joint, care should be exercised to avoid building up the fillet too high.

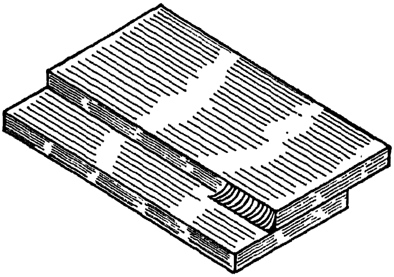


Fig. 41. Lap Joint

Practice Weld

Secure two pieces of 1/16″ or 1/8″ metal 4″ to 5″ in length. Lay the plates on firebricks with one piece of metal overlapping, as in Fig. 41.

Weld the two plates, using a

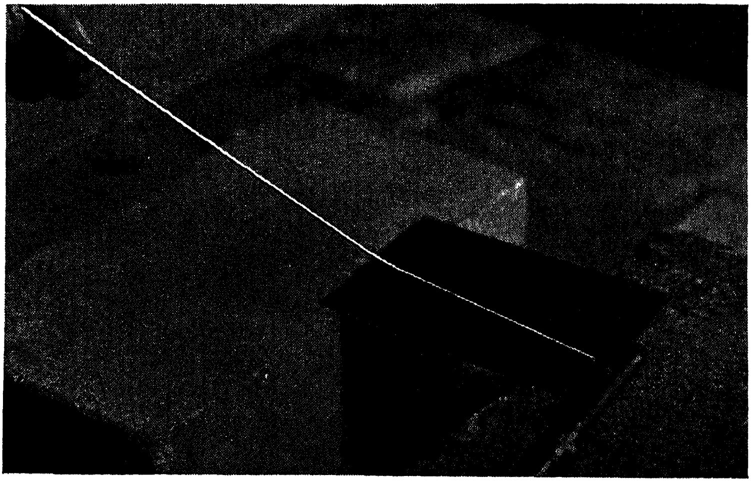


Fig. 42. Position of Torch and Rod for a Lap Weld

semicircular movement of the torch and working from right to left. Since it will require less heat to melt the edge of the upper plate than the flat surface of the lower metal, it is essential to direct more heat onto the lower plate than the top one to make a satisfactory weld. This may be accomplished by prolonging the travel of the arc on the lower surface and cutting short the arc on the edge of the upper metal. Weld one side of the plate, and then practice on the reverse side. Repeat the exercise until a satisfactory weld is made.

QUESTIONS

1. What should be the direction of the welding for this exercise?
2. How does a lap weld differ from a butt weld?
3. Describe the motion of the torch for a lap weld.
4. Why is the length of the arc prolonged on the bottom plate of a lap joint?
5. Where should the puddle be formed on this joint?

Unit 11

WELDING A TEE JOINT

Another common joint with which a welder should be familiar is the tee joint. This joint is made by standing a vertical piece of metal at right angles to a horizontal plate. The exercise is to be carried out with the same size metal and welding rod as in the previous welds.

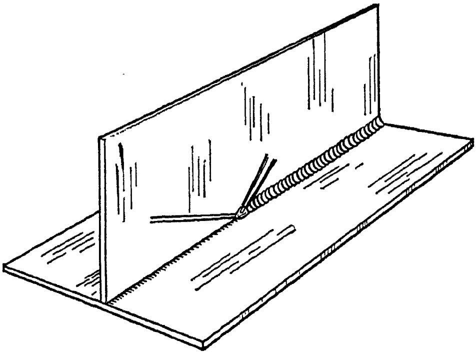


Fig. 43. Welding a Tee Joint

Practice Weld

Secure two pieces of metal 4″ to 5″ in length and place on firebricks as shown in Fig. 43. Tack the ends of the joint, then start welding at the right end, proceeding to the left with a semicircular torch movement.

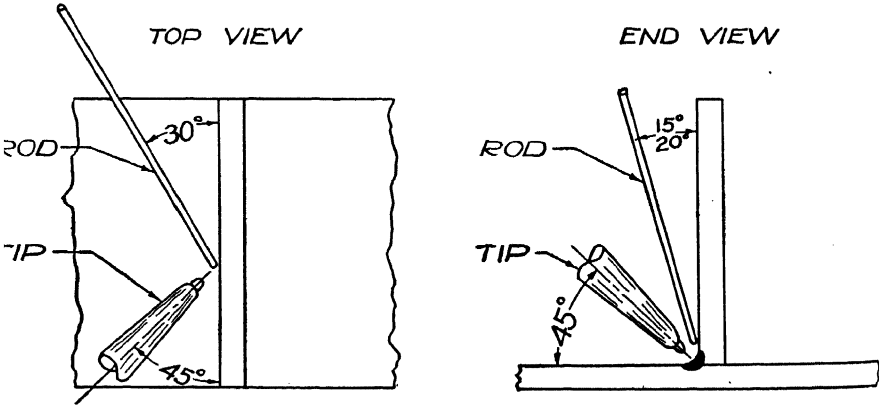


Fig. 44. Position of Torch and Rod for Welding a Tee Joint

Hold the torch so that the tip forms an angle of about 45 degrees to the flat plate and the same angle to the line of the weld. The end of the rod should be pointed toward the tip at an angle of approximately 30 degrees to the line of weld and 15 to 20 degrees to the horizontal plate. See Fig. 44.

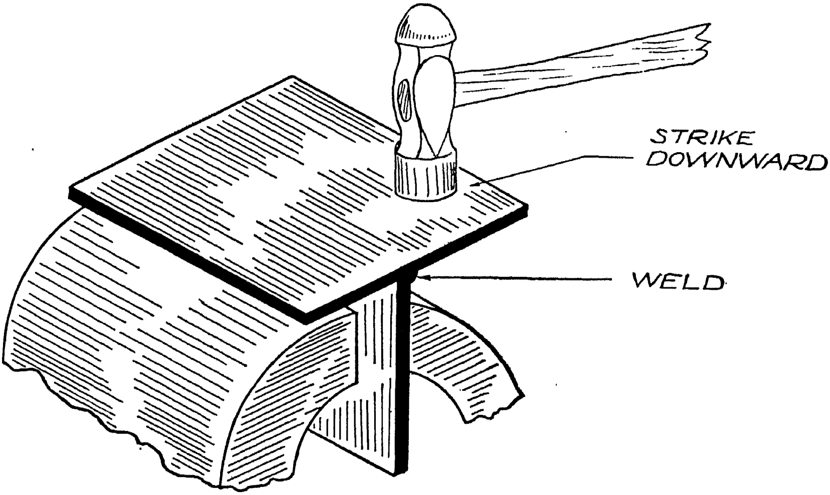


Fig. 45. Testing a Tee Joint

Direct the flame evenly over both plates, keeping the inner cone of the flame about ⅛″ away from the surface. In a weld of this type the beginner usually has a tendency to heat the vertical plate too much, causing an undercutting above the weld. Keep the molten puddle moving forward, adding the rod nearer the vertical plate.

Testing the Weld

Pick up the weld with a pair of pliers and check for defects. Test its strength and repeat the exercise until a good weld is obtained.

QUESTIONS

1. How is a tee joint welded?
2. What precautions should be observed in welding this joint?
3. If the metal does not melt freely, what should be done?
4. What should be the position of the torch for welding the tee joint?
5. How can you check the weld for penetration?

Unit 12

OXYGEN AND ACETYLENE

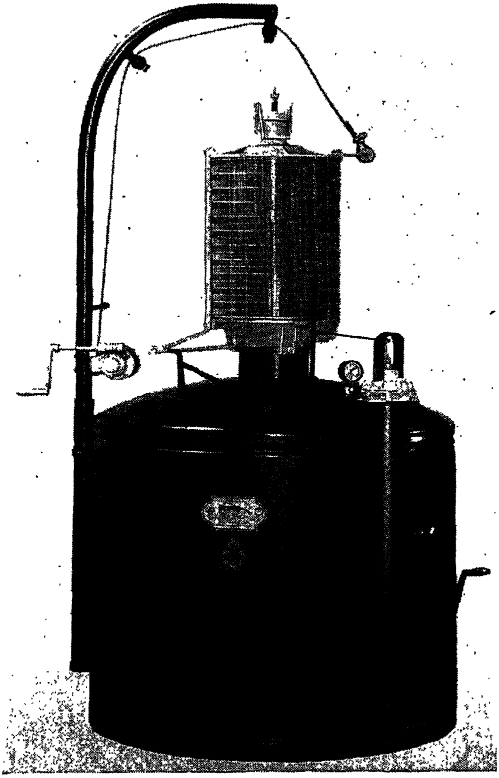
ALTHOUGH A WELDER is not particularly concerned with exacting details for the manufacturing of oxygen and acetylene, nevertheless he should have a general idea as to how these gases are produced.

Oxygen

The atmosphere which we commonly refer to as air is composed of 20 per cent oxygen, the rest being nitrogen with a small percentage of rarer gases such as helium, neon, and argon. To obtain the oxygen in a state that makes it usable for welding or other purposes, it is necessary to separate it from the other gases.

There are two general methods that may be used to produce oxygen, namely the electrolytic and the liquid-air process. In the electrolytic process, the fact is utilized that, water being a chemical compound consisting of oxygen and hydrogen, by the sending of a current through a solution of water containing caustic soda, oxygen will be isolated at one terminal plate and hydrogen at the other, thereby making possible the separation of the two gases. Because of the greater cost in manufacturing oxygen in this manner, the liquid-air method is more commonly used to produce commercial oxygen rather than the electrolytic process.

In a plant where oxygen is made by the liquid air method, the air is drawn from the outside into huge containers known as washing towers, where the air is washed and purified of carbon dioxide. A solution of caustic soda is used to wash the air, this solution being run from a nearby tank and circulated through the towers by means of centrifugal pumps. As the air leaves the washing towers, it is compressed and passed through what are known as oil-purging cylinders in which oil particles or any water vapors are removed. From this point the air goes into drying cylinders. These cylinders contain dry, caustic potash which dries the air, removing any further carbon dioxide and water vapor. On the top of each cylinder special cotton filters are provided to prevent any particles of foreign matter from being carried into the high-pressure lines. The dry, clear, compressed air then goes into the rectifying or liquification columns where the air is cooled and expanded to approximately atmospheric pressure. This process of changing the extremely cold air under high pressure to the lower atmospheric pressure causes the air to liquify. The separation of the nitrogen from the oxygen becomes possible at this point because of the difference in the boiling point between nitrogen (–320 degrees F.) and oxygen (–296 degrees F.). The nitrogen, having a lower boiling point, evaporates first, leaving the oxygen in a liquid state in the bottom of the condenser. The liquid oxygen next passes through a heated coil which changes the liquid into a gaseous form. From here the gas goes into a storage tank, passing through a gas meter which registers the amount of gas entering the storage tank. The gas is then drawn from this tank and compressed to a pressure of about 2000 pounds per square inch, after which it is forced into the receiving cylinders by manifolds.



COURTESY NATIONAL CYLINDER GAS COMPANY AND PURITY CYLINDER GASES

Fig. 46. Acetylene Generator

Acetylene

Acetylene is a gas formed by the mixture of calcium carbide and water. The generator in which the gas is made consists of a huge tank containing a large amount of water. A certain quantity of carbide is dumped into a hopper and raised to the top of the generator. Then the carbide is allowed to fall into the water, and, upon its coming in contact with the water, bubbles of gas are given off. This gas is collected, purified, cooled, and slowly compressed into cylinders containing acetone.

Acetylene is a colorless gas, with a very distinctive, nauseating odor. It is highly combustible when mixed with oxygen or air. Although it is stable under low pressure at normal temperatures, it becomes very unstable if compressed to a pressure greater than 15 pounds per square inch.

QUESTIONS

1. What are some of the principal gases which make up what is commonly referred to as air?
2. Name two general methods used in making oxygen.
3. What is the function of the washing tower in a liquid-air manufacturing plant?
4. What are the functions of filters on the tops of the drying cylinders?
5. What is the function of the rectifying columns?
6. What principles make possible the separation of nitrogen from the oxygen?
7. How is liquid oxygen changed into a gaseous form?
8. What is the function of the gas meter?
9. To what pressure are the oxygen cylinders charged?
10. How is acetylene produced?

Unit 13

HORIZONTAL WELDING

SINCE ALL WELDING cannot be done on a flat bench top, a good welder should be able to weld in a number of different positions. Regardless of where the joint may be located, the weld must be carried out with the same amount of skill.

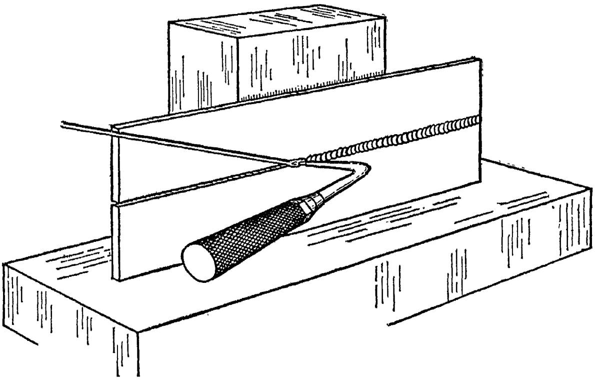


Fig. 47. Horizontal Welding

Practice Weld

Tack two pieces of metal and set up edgewise on firebricks as shown in Fig. 47. Hold the torch in a horizontal position and direct the flame as nearly as possible at the same angle to the metal as in welding a level seam, using a semicircular motion of the torch. When the work is on the eye level of the operator, it is possible to manipulate the torch in a vertical position. If the puddle has a tendency to sag, whip the flame away for a second to reduce the heat. Watch the travel of the flame very closely to avoid directing the flame too much on one side of the joint and not enough on the other.

When attempting this exercise, it is perhaps better if the plates are inclined to about a 45-degree angle for the first few welds, since at this angle the welding is considerably easier. As the technique is improved, gradually raise the plates until they are in a vertical position.

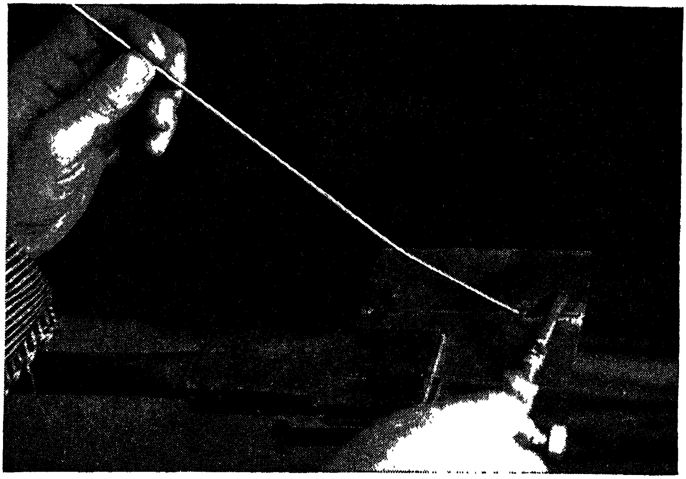


Fig. 48. Butt Weld at a 45° Angle

Testing Weld

Test the weld as in the previous lessons. Repeat the exercise until a satisfactory weld is obtained.

QUESTIONS

1. Why should a welder be capable of welding in different positions?
2. How should the plates be set up for horizontal welding?
3. Describe the position of the torch for horizontal welding.
4. When is it possible to hold the torch in a vertical position for a horizontal weld?
5. If the puddle has a tendency to sag, what should be done? Why?

VERTICAL WELDING

It frequently happens that a weld must be made on a vertical seam. Although the experienced welder finds this weld no more difficult than in making a flat weld, the beginner will need some practice to master the technique. The skill that must be acquired for this type of weld is the ability to move the puddle upward in a vertical line without having the puddle sag and the molten metal drop off.

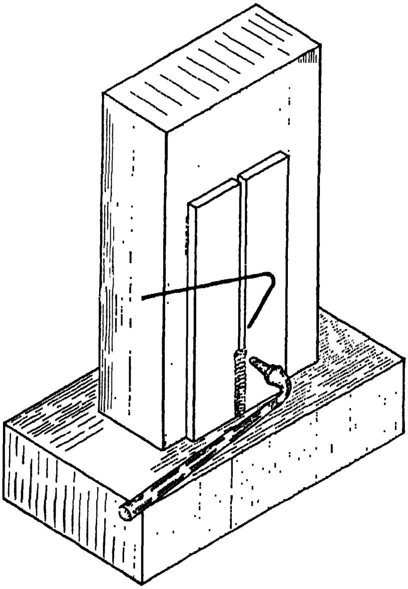


Fig. 49. Vertical Welding

Practice Weld

Set up two pieces of 1/16″ or 1/8″ metal on firebricks so that the seam is in a vertical position. See Fig. 49. Begin welding at the bottom and work the torch upward, using a semicircular motion. Hold the torch in a horizontal position with the tip inclined upward at an angle of about 50 degrees. Avoid adding too much filler rod, and, if the puddle begins to sag, whip the torch away for an instant to reduce the heat.

This exercise also should be started first with the plates inclined approximately 45 degrees and then gradually raised until the weld is carried up in a vertical position. It will also be found that if the

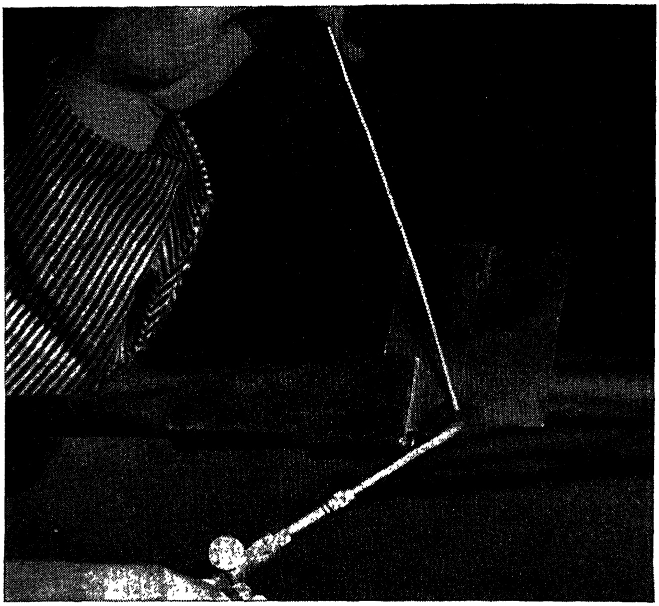


Fig. 50. A 45° Vertical Butt Weld

rod is held at a 20-degree angle from the surface of the plates, a much better control of the puddle is secured.

QUESTIONS

1. What is meant by vertical welding?
2. What skill needs to be learned for vertical welding?
3. How is it possible to prevent the puddle from sagging?
4. Why should filler rod be added sparingly?
5. What is the position of the torch in vertical welding?

BACKWARD WELDING

THERE ARE TWO general methods of welding, known as the forward and the backward weld. See Fig. 51. The forward method has been described in the previous lessons, i.e., the one in which the welding rod is held in front of the flame with the deposited metal in back of the flame and the direction of travel being from right to left. In the backward method, the rod is held back of the flame; the flame is in front of both the rod and the deposited metal, and the direction of travel is from left to right. In other words the technique of the backhand weld is exactly opposite to that used in executing the forehand weld. The semicircular motion of the torch must be reversed so that the base of the arc again falls towards the metal that is being deposited. See Fig. 52.

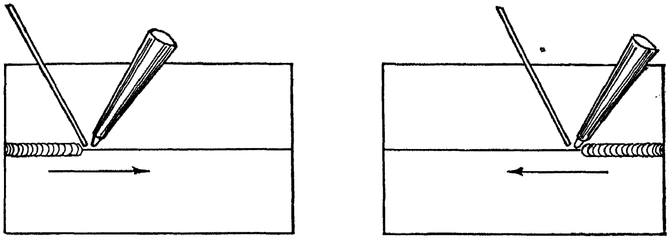

Backhand *Forehand*

Fig. 51. Welding Methods

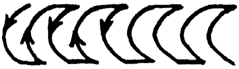


Fig. 52. Direction of Weld

A welder must be proficient in both these techniques. Although the beginner will find the backward weld somewhat awkward to start with, a little practice is all that is needed to acquire the knack of moving the torch in this manner. The backward weld should first be tried in fusing the edges of an L joint, as shown in Fig. 53.

Practice Weld

Set up two 1/16″ or 1/8″ plates on firebricks so as to form an L with the corner facing upward. Tack the plates on both ends and begin welding at the left, proceeding to the right and using a semicircular movement of the torch. Be sure the metal is fusing properly before adding the rod. The beginner, when first attempting a backward weld, will have a tendency to direct the flame more on the rod than on the plate, causing the molten drops from the rod to pile up and form beads of cold metal. This should be watched very closely, as improper fusion will result in a weak joint. Add sufficient material to build up the corner to a height of slightly more than the thickness of the plate.

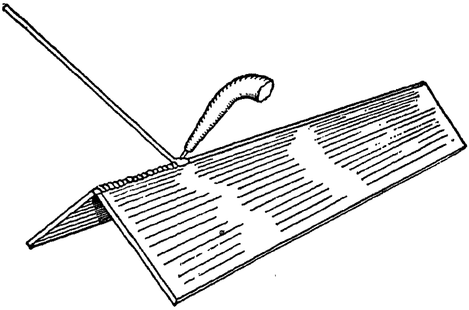


Fig. 53. Welding an L Joint

Testing the Weld

Examine the joint for penetration, and then test the weld by bending. Repeat the weld if the joint fails to hold.

To gain more skill in the use of this method, practice welding a butt, lap, and tee joint.

QUESTIONS

1. Name and describe the two general methods of welding.
2. Why is skill in the use of both methods essential to a welder?
3. Describe the movement of the torch for the backward weld.
4. How much filler rod should be added in welding the plates for an L joint?
5. What precaution should be observed in making a backward weld?

Unit 16

OVERHEAD WELDING

ONE OF THE SLIGHTLY more difficult welds to perform is the overhead weld. This type of welding is somewhat harder to perform because of the unusual position in which the operator is required to work and the skill needed to keep the molten puddle from running off the plates.

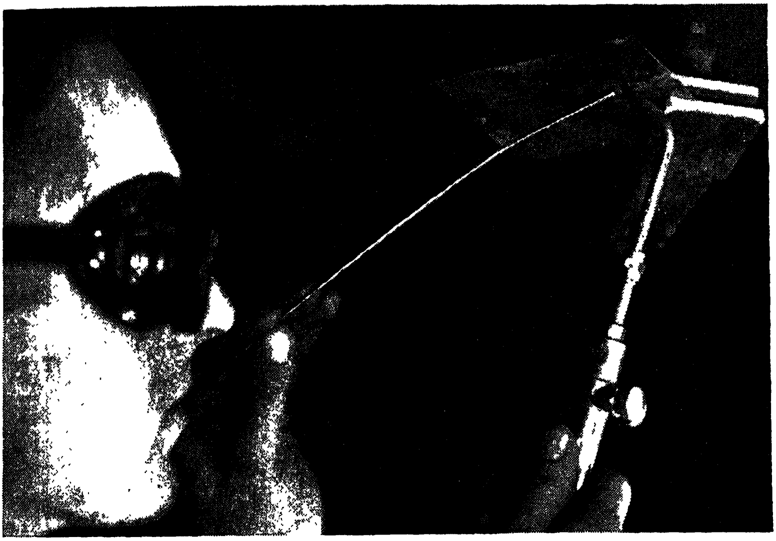


Fig. 54. Position for Overhead Welding

Overhead welding is possible because of the fact that molten metal has cohesive qualities as long as the puddle is not permitted to get too large. In other words, molten metal will resist the laws of gravity if the puddle is not allowed to form in complete drops. The amount of heat directed on the seam must be very carefully regulated, since too-intense heat will increase the flow of the molten metal. With the correct flame, proper torch manipulation, and practice, the overhead weld can be mastered quickly.

Practice Weld

Tack two 1/16″ or 1/8″ plates together and set work up on a suitable jig that will permit sufficient freedom for manipulating the torch. Use the same semicircular motion of the torch as previously described. To help keep the puddle shallow, move the filler rod slowly in a circular or swinging motion. The movement of the rod will distribute the molten puddle and prevent it from forming into large drops and falling off. Watch the flame very closely, and, if the puddle has a tendency to run, pull the torch away slightly.

Testing Joint

Cool the welded piece and subject it to the bending test. Continue practicing overhead welds until satisfactory joints that will not break are produced.

QUESTIONS

1. What is meant by overhead welding?
2. Why is this type of welding somewhat more difficult to perform?
3. What prevents the puddle from falling off the plate?
4. What torch movement should be used for this type of welding?
5. Why should the rod be moved in overhead welding?

Unit 17

IDENTIFICATION OF METALS

SINCE THE COMPOSITION of metals varies, a welder must be able to recognize the characteristics of different metals to weld them successfully. The most common practice employed in the shop to distinguish one metal from another is by means of the spark test. This consists simply of bringing the metal against a revolving emery wheel and noting the characteristics of the sparks. After a little practice one readily learns to recognize the meaning of these sparks and quickly identify the type of metal.

Wrought Iron

Wrought iron is practically a pure form of iron, containing quantities of slag mixed in with the metal while it was in a molten condition. This metal may be identified by the ease with which it can be bent, shaped, or cut. It has a light gray appearance with a smooth surface. Since it lacks any appreciable amount of carbon, it cannot be heat-treated or hardened. Although soft, it is very tough and will not fracture easily. If subjected to the spark test, wrought iron will throw off long streamers that are straw-yellow in color. There are very few sparklers, indicating an absence of carbon. See Fig. 55.

Carbon Steels

The important added element in steel is carbon, as the amount of this ingredient governs the grade and quality of the steel. In general, it may be stated that the greater the carbon content the harder the steel, and the more difficult it is to weld.

Carbon steels may be sub-divided into three groups: *1.* low-carbon steel, 2. medium-carbon steel, and 3. high-carbon steel.

The quality of carbon steel also depends on the percentage of impurities it contains. The two most undesirable elements are sulphur and phosphorus, since they have a tendency to make steel brittle. Consequently, the lower the percentage of these two elements, the better the steel.

Two other elements that are found in carbon steel, and which are carefully controlled, are manganese and silicon. Manganese in certain small quantities is advantageous to steel, since it acts as an agent for eliminating the detrimental effects of impurities. In larger amounts, manganese increases the hardness of steel. Silicon, like manganese, acts as a cleanser and purifier and imparts toughness and hardness to the metal.

Low-Carbon Steel

Low-carbon steel, often referred to as machine steel, contains carbon ranging from 0.10 per cent to approximately 0.25 per cent. This type is used for parts where great strength is not important, such as in the manufacture of rivets, nails, wire, structural plates, etc.

Since the carbon content is low, this metal is not very hard, permitting greater ease in machining, forging, bending, and welding. It cannot be heat-treated, but it does lend itself very well to case-hardening. Low-carbon steel, when subjected to the spark test, will throw off long, white-colored streamers with very little or no sparklers. See Fig. 55.

Medium-Carbon Steel

Steel whose carbon content ranges from about 0.26 per cent to 0.50–0.60 per cent is generally classified as a medium-carbon steel. This metal is used for parts where greater strength is required, such as in certain types of axles, forgings, boiler plates, etc. Although medium-carbon steel does not weld or machine nearly as easily as low-carbon steel, the higher carbon content insures greater toughness and strength.

The spark test will show more numerous sparklers, beginning closer to the wheel, with the streamers much lighter in color.

High-Carbon Steel

The carbon content of high-carbon steel will range from approximately 0.60 per cent to 1.5 per cent. This type of steel is generally known as tool steel, since it is used for making many kinds of tools. The outstanding characteristic of this metal is its ability to become very hard when heated and quenched in a bath of water or oil.

The spark test for tool steels can easily be recognized by the numerous explosions or sparklers given off, which are practically white in color. See Fig. 55.

Alloy Steels

Alloy steels are steels that contain small quantities of other elements in addition to carbon, silicon, phosphorous, and sulphur. The principal alloying elements usually are manganese, nickel, chromium, tungsten, molybdenum, or vanadium. In many instances more than one of these ingredients are used to obtain the desired quality of steel. The addition of these substances produces a far superior steel, greater in strength, toughness, tensile resistance, durability, etc. Alloy steels are known by their main alloying elements, such as nickel steel, chrome-nickel steel, manganese steel, etc.

Considerable skill is necessary to weld alloy steels, and in most cases a special welding rod is required.

As a general rule most alloy steels are somewhat more difficult to identify by the spark test. However, when alloying elements are added, the resulting products do have certain noticeable spark characteristics. The sparkings for a few of the more common alloy steels are shown in Fig. 55.

Cold-roll Steel

Cold-roll steel comes either in sheets or bars and, as the name implies, is steel that has been rolled cold in the last stages of reducing it to the required shape and size. This process produces a metal that has a very smooth surface, and is very accurate in dimensional sizes.

Cast Iron

Cast iron contains a considerable amount of carbon, ranging from 2.5 per cent to 4 per cent, making the metal very brittle. Unlike

SIMPLE TESTS FOR

To Aid in the Determination of Cor-

		WHITE CAST IRON	GRAY CAST IRON	MALLEABLE* IRON	WROUGHT IRON	LOW-CARBON STEEL AND CAST STEEL
APPEARANCE	FRACTURE	Very fine, silvery-white, silky, crystalline formation	Dark gray	Dark gray	Bright gray	Bright gray
	UNFINISHED SURFACE	Evidence of sand mold; dull gray	Evidence of sand mold; very dull gray	Evidence of sand mold; dull gray	Light gray, smooth	Dark gray; forging marks may be noticeable; cast—evidences of mould
	NEWLY MACHINED SURFACE	Rarely machined	Fairly smooth; light gray	Smooth surface; light gray	Very smooth surface; light gray	Very smooth; bright gray
CHIP TEST	APPEARANCE OF CHIP	Small broken fragments	Small, partially broken chips but possible to chip a fairly smooth groove	Chips do not break short as in cast iron	Smooth edges where cut	Smooth edges where cut
	SIZE OF CHIP		⅛ in.	¼-⅜ in.	Can be continuous if desired	Can be continuous if desired
	FACILITY OF CHIPPING	Brittleness prevents chipping a path with smooth sides	Not easy to chip because chips break off from base metal	Very tough; therefore harder to chip than cast iron	Soft and easily cut or chipped	Easily cut or chipped
SPARK TEST	COLOR, SHAPE, AVERAGE LENGTH WITH POWER GRINDER, AND ACTIVITY OF SPARKS ARE DISTINGUISHING DETAILS	Color, straw yellow; average length with power grinder, 20 in.; volume very small; fewer sparklers than gray cast iron; sparklers are small and repeating	Color, straw yellow; average length with power grinder, 25 in.; volume small; many sparklers; sparklers are small and repeating	Color, straw yellow; average length with power grinder, 30 in.; volume moderate; many sparklers; sparklers are small and repeating	Color, straw yellow to white; average length with power grinder, 65 in.; volume large; very few sparklers; sparklers are forked.	Color, white; average length with power grinder, 70 in.; volume moderately large; few sparklers; sparklers are forked.
BLOWPIPE TEST	SPEED OF MELTING (From Cold State)	Moderate	Moderate	Moderate	Fast	Fast
	COLOR CHANGE WHILE HEATING	Becomes dull red before melting	Becomes dull red before melting	Becomes red before melting	Becomes bright red before melting	Becomes bright red before melting
	APPEARANCE OF SLAG	A medium film develops	A thick film develops	A medium film develops	Oily or greasy appearance with white lines	Similar to molten metal
	ACTION OF SLAG	Quiet; tough, but can be broken up	Quiet; tough, but possible to break it up	Quiet; tough, but can be broken	Quiet; easily broken up	Quiet
	APPEARANCE OF MOLTEN PUDDLE	Fluid and watery; reddish white	Fluid and watery; reddish white	Fluid and watery; straw color	Liquid; straw color	Liquid; straw color
	ACTION OF MOLTEN PUDDLE UNDER BLOWPIPE FLAME	Quiet; no sparks; depression under flame disappears when flame is removed	Quiet; no sparks; depression under flame disappears when flame is removed	Boils and leaves blowholes; surface metal sparks; interior does not	Does not get viscous; generally quiet; may be slight tendency to spark	Molten metal sparks

° Very seldom used commercially.

* Malleable iron should always be bronze-welded.

** Alloy steels vary so much in composition and, consequently, in results of tests that experience is the best solution to identification problems. Stainless-steel spark test is shown.

IDENTIFYING METALS

rect Oxy-Acetylene Welding Procedure

HIGH-CARBON STEEL	ALLOY** STEEL	COPPER	BRASS AND BRONZE	ALUMINUM AND ALLOYS†	MONEL METAL	NICKEL	LEAD††
Very light gray	Medium gray	Red color	Red to yellow	White	Light gray	Almost white	White; crystalline
Dark gray; rolling or forging lines may be noticeable	Dark gray; relatively rough; rolling or forging lines may be noticeable	Various degrees of reddish brown to green due to oxides; smooth	Various shades of green, brown, or yellow due to oxides; smooth	Evidences of mold or rolls; very light gray	Smooth; dark gray	Smooth; dark gray	Smooth; velvety; white to gray
Very smooth; bright gray	Very smooth; bright gray	Bright copper-red color dulls with time	Red through to whitish yellow; very smooth	Smooth; very white	Very smooth; light gray	Very smooth; white	Very smooth; white
Fine grain fracture; edges lighter in color than low-carbon steel	**	Smooth chips; saw edges where cut	Smooth chips; saw edges where cut	Smooth chips; saw edges where cut	Smooth edges	Smooth edges	Any shaped chip can be secured because of softness
Can be continuous if desired	**	Can be continuous if desired	Can be continuous if desired	Can be continuous if desired	Can be continuous if desired	Can be continuous if desired	Can be continuous if desired
Metal is usually very hard but can be chipped	**	Very easily cut	Easily cut; more brittle than copper	Very easily cut	Chips easily	Chips easily	Chips so easily it can be cut with penknife
Color, white; average length with power grinder, 55 in.; volume large; very many sparklers; sparklers are small and repeating.	Color, straw yellow to white; average length with power grinder, 50 in.; volume moderate; moderate number of sparklers; sparklers are forked.	No spark	No spark	No spark	Spark very similar to nickel	Color, orange; average length with power grinder, 10 in.; volume, very small wavy streaks, no sparklers.	No spark
Fast	**	Slow	Moderate to fast	Faster than steel	Slower than steel	Slower than steel	Very fast
Becomes bright red before melting	**	May turn black and then red; copper color may become more intense	Becomes noticeably red before melting	No apparent change in color	Becomes red before melting	Becomes red before melting	No apparent change
Similar to molten metal	**	So little slag that it is hardly noticeable	Various quantities of white fumes, though bronze may not have any	Stiff black scum	Gray scum; considerable amounts	Gray scum; less slag than Monel metal	Dull gray coating
Quiet	**	Quiet	Appears as fumes	Quiet	Quiet; hard to break	Quiet; hard to break	Quiet
Lighter than low-carbon steel, has a cellular appearance	**	Has mirrorlike surface directly under flame	Liquid	Same color as unheated metal; very fluid under slag	Fluid under slag	Fluid under slag film	White and fluid under slag
Sparks more freely than low-carbon steel	**	Tendency to bubble; puddle solidifies slowly and may sink slightly	Like drops of water; with oxidizing flame, will bubble	Quiet	Quiet	Quiet	Quiet; may boil if too hot

COURTESY OF THE LINDE AIR PRODUCTS COMPANY

† Due to white or light color and extremely light weight, aluminum is usually easily distinguishable from all other metals; aluminum alloys are usually harder and slightly darker in color than pure aluminum.

†† Weight, softness, and great ductility are distinguishing characteristics of lead.

CHARACTERISTICS OF SPARKS

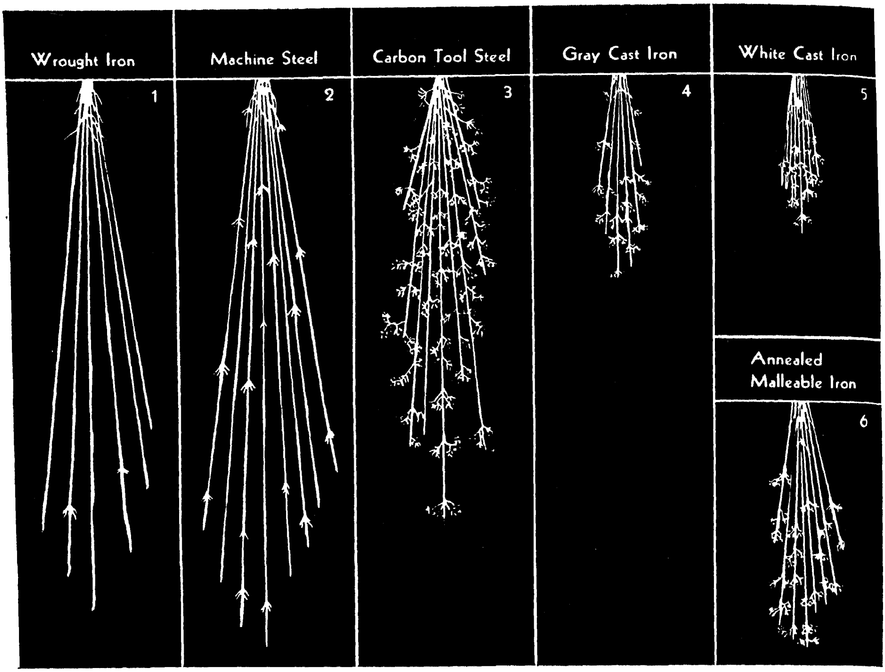


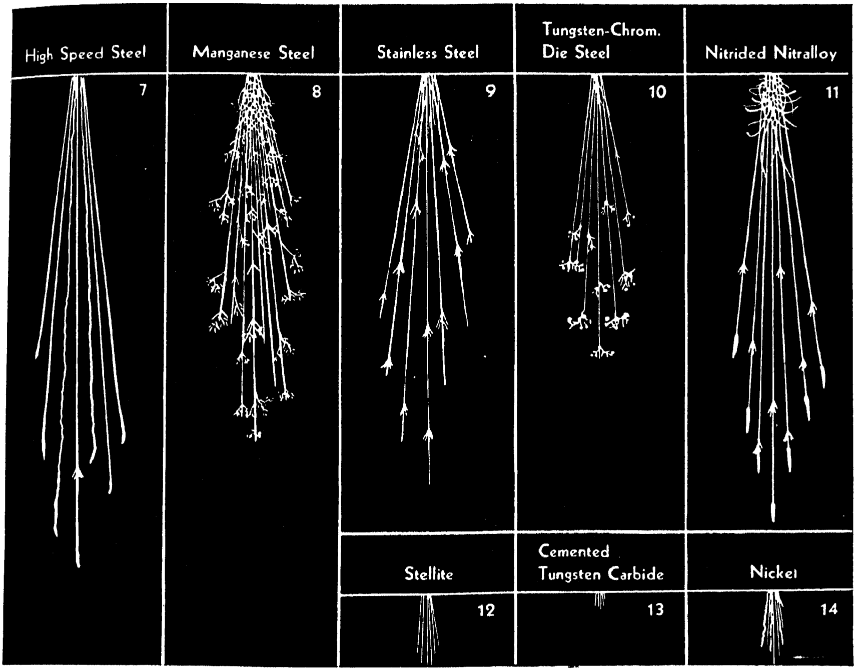
Fig. 55

Metal	Volume of Stream	Relative Length of Stream, Inches †
1. Wrought iron	Large	65
2. Machine steel	Large	70
3. Carbon tool steel	Moderately large	55
4. Gray cast iron	Small	25
5. White cast iron	Very small	20
6. Annealed malleable iron	Moderate	30
7. High-speed steel	Small	60
8. Manganese steel	Moderately large	45
9. Stainless steel	Moderate	50
10. Tungsten-chromium die steel	Small	35
11. Nitrided Nitralloy	Large (curved)	55
12. Stellite	Very small	10
13. Cemented tungsten carbide	Extremely small	2
14. Nickel	Very small **	10
15. Copper, brass, aluminum	None	

† Figures obtained with 12″ wheel on bench stand and are relative only. Actual length in each instance will vary with grinding wheel, pressure, etc.

** Some wavy streaks.

IN THE GRINDING OF METALS



COURTESY NORTON COMPANY

Color of Stream Close to Wheel	Color of Streaks Near End of Stream	Quantity of Spurts	Nature of Spurts
Straw	White	Very few	Forked
White	White	Few	Forked
White	White	Very many	Fine, repeating
Red	Straw	Many	Fine, repeating
Red	Straw	Few	Fine, repeating
Red	Straw	Many	Fine, repeating
Red	Straw	Extremely few	Forked
White	White	Many	Fine, repeating
Straw	White	Moderate	Forked
Red	Straw *	Many	Fine, repeating *
White	White	Moderate	Forked
Orange	Orange	None	
Light Orange	Light Orange	None	
Orange	Orange	None	
		None	

* Blue-white spurts.

steel, cast iron does not possess a great deal of strength or malleability. It does have certain definite advantages that make it ideal for castings. Due to the large amounts of impurities, cast iron is fluid; it shrinks very little during solidification; it has a lower melting point; and finally, it is much less costly than steel, all of which are important qualities in the making of castings.

Cast iron is classed in three groups, gray, white, and malleable.

The factors determining the quality and type of cast iron depend largely on the content of silicon and the presence of carbon either in a graphitic or combined state (see explanation of this term under *white cast iron* below). When the silicon content is high and the molten metal allowed to cool slowly, there is a separation of the carbon from the metallic iron, the carbon remaining free in large flakes. It is this separation of the carbon from the iron that makes gray cast iron very brittle.

The identity of a piece of gray cast iron will be easily recognized by the dark gray, porous structure. When brought in contact with a revolving emery wheel, the metal will give off thin short streamers that follow a straight line and are brick red in color, with numerous fine, repeating spurts. See Fig. 55.

White Cast Iron

When cast iron possesses what is known as combined carbon, the resulting metal is called white cast iron. Combined carbon simply means that the carbon element has been made to actually unite with the iron, instead of existing in a free state as in gray cast iron. This condition is brought about through the process of rapidly cooling the casting, leaving a metal that is very hard and brittle. In fact it is so hard that it is exceedingly difficult to machine, and special cutting tools or grinders must be used to cut the metal. White cast iron is generally used for making malleable castings.

The fracture of a piece of white cast iron will indicate a fine, silvery white, silky, crystalline formation. The spark test will show very short streamers that are red in color. There are very few spurts and these are fine and repeating. See Fig. 55.

Malleable Iron

When castings require high strength, ductility, and shock-absorbing qualities, they are given special treatment which leaves the iron in a malleable state. White cast iron is used for these castings. The castings are placed in a furnace and heated to approximately 1700 degrees F. for a long time and then cooled slowly. This annealing treatment draws out the brittleness from the castings, leaving the metal soft but possessing considerable toughness.

The fracture of a piece of malleable iron will disclose a white rim and a dark center. The spark test will show a moderate amount of short, orange-red streamers with numerous sparklers that are small and repeating. See Fig. 55.

The S.A.E. Steel Numbering System

Since it is practically impossible to accurately distinguish the vast varieties of steels, a number of years ago the Society of Automotive Engineers devised a numbering system for the purpose of identifying the different types of steels. These numbers designate the carbon and principal alloying elements for each steel and their approximate amounts. The first number classifies the types of steel: for example, *1* represents carbon steel, *2* nickel, *3* nickel chromium, etc. In the case of alloy steels the second number of the series indicates the approximate amount of the predominating alloying element. The last two or three digits refer to the carbon content and are expressed in hundredths of 1 per cent. For example, a *2335 S.A.E.* steel indicates nickel steel of about 3 per cent nickel and 0.35 per cent carbon.

The following are the basic numerals for various S.A.E. steels:

TYPE OF STEEL	NUMERAL
Carbon Steels	1 xxx
Plain carbon	10 xx
Free cutting (screw stock)	11 xx
Free cutting, manganese	x13 xx
High manganese	T13 xx
Nickel Steels	2 xxx
.50% nickel	20 xx
1.50% nickel	21 xx
3.50% nickel	23 xx
5.00% nickel	25 xx
Nickel Chromium Steel	3 xxx
1.25% nickel; 60% chromium	31 xx
1.75% nickel; 1.00% chromium	32 xx
3.50% nickel; 1.50% chromium	33 xx
3.00% nickel; .80% chromium	34 xx

Corrosion and Heat-resisting Steels	30 xxx
Molybdenum Steels	4 xxx
Chromium	41 xx
Chromium nickel	43 xx
Nickel	46 xx and 48 xx
Chromium Steel	5 xxx
Low Chromium	51 xx
Medium Chromium	52 xxx
Corrosion and heat resisting	51 xxx
Chromium Vanadium Steel	6 xxx
Tungsten Steel	7 xxx and 7 xxxx
Silicon Manganese Steel	9 xxx

QUESTIONS

1. For what is cast iron used?
2. What makes cast iron very brittle?
3. Name four types of cast iron.
4. What is the difference between gray and white cast iron?
5. How can gray cast iron be identified?
6. Why is white cast iron difficult to machine?
7. For what is white cast iron generally used?
8. How can you identify white cast iron?
9. What is malleable iron?
10. How can malleable iron be identified?
11. What is wrought iron?
12. Why is wrought iron so easy to bend or shape?
13. In what two ways may steel be classified?
14. Why is carbon the important added element in carbon steels?
15. Name the three groups into which carbon steels may be divided.
16. What are some of the factors that characterize low-carbon steel?
17. Why is it difficult to harden low-carbon steel?
18. What is the difference between medium- and high-carbon steel?
19. What will the spark test show for low-carbon steel?
20. How can high-carbon steel be distinguished from low-carbon steel?
21. What is the purpose of the S.A.E. steel-numbering system?
22. What do the numbers of this system represent?
23. What would be the analysis of steel marked *S.A.E. 1090, 3115, 2345?*
24. What is meant by an alloy steel?
25. What are some of the alloying elements that are added to steel?

PROBLEM

Select samples of all the different kinds of metals that are available and identify them by the spark test.

When you have become familiar with these various metals through the spark test and can tell at a glance whether the metal is a low-carbon or high-carbon steel, etc., subject the pieces of metal to the melting test. Study the characteristics of these metals as given in the identification chart. Then place the sample pieces on the welding bench and, using a neutral flame, melt first one metal and then another. During the process of melting the metals, note the reactions, such as sparks, rapidity in melting, ease of flow, etc.

Unit 18

EXPANSION AND CONTRACTION

IN THE STUDY of the characteristics of metals there is still another important factor that must be considered by the welder, namely, expansion and contraction. A welder must know just what effect expansion and contraction forces have on different kinds of metal and what must be done to counteract them.

Whenever heat is applied to a piece of metal, expansion forces are liberated which tend to change the volume as well as the linear dimensions of the piece. Upon cooling, the metal undergoes a change again as it attempts to resume its original shape. No serious consideration must be given these elements when there are no restricting forces to prevent the free movements of the expansion and contraction forces. When these forces are arrested of their free movements there is likely to occur a warping or distortion if the metal is malleable or ductile, and a fracture if the metal is brittle, as in cast iron.

To show just how the expansion and contraction forces affect metal let us study the result of welding two different pieces. In the first case assume a break has occurred in the middle of a bar, as in Fig. 56.

Upon welding the break the heat naturally will cause the metal to expand. Since there are no obstructions on the ends of the bar the metal is permitted to move to whatever limits it desires. When the piece begins to cool there are still no forces that prevent the metal from assuming its original shape. Suppose this bar were a center section, Fig. 57.

It will be noticed that in this case the ends of the bar are rigidly fastened to a solid frame. If the same procedure were used to weld the fracture as in the first case, it is evident that something is bound to happen to the casting if no provisions are made for expansion and contraction. Since the vertical and horizontal sections of the frame will prevent expanding the ends of the center piece there is only one direction in which this movement can take place while the metal is being heated, and that is at the point where fusion is to take place. Now consider what will happen when this section begins to cool.

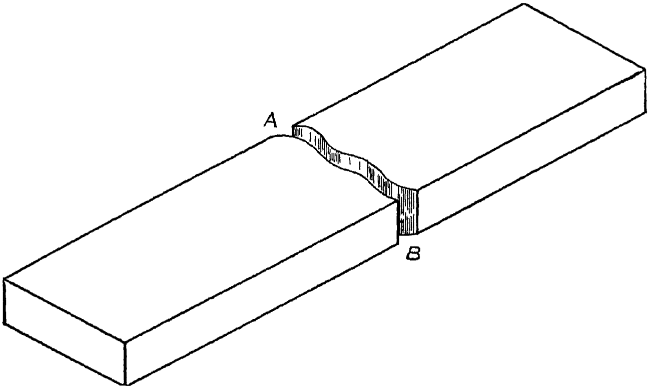


Fig. 56. Effects of Expansion and Contraction Forces on Open Metal

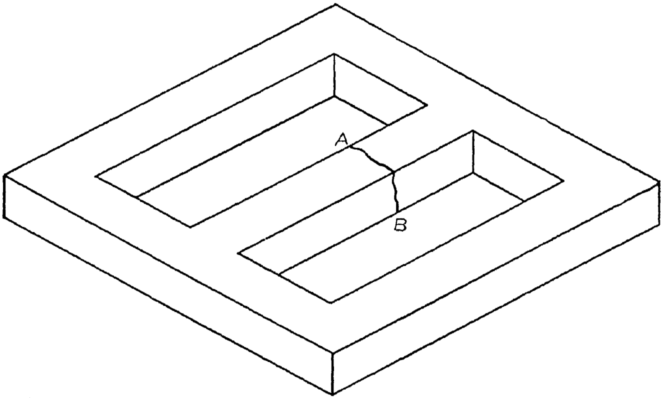


Fig. 57. Effects of Expansion and Contraction Forces on Closed Metal

The frame around the center section has not moved and, when contraction sets in, the center piece will be shortened and when the rigid frame resists this pull a fracture or deformation at the line of weld or in some other place is bound to occur.

On the other hand if, before the break were welded, the entire casting had been heated there would have been an equal amount of expansion in the entire piece causing the two ends of the fracture to draw away. When the weld is made the entire frame will shrink approximately an equal amount.

This is only a very simple illustration but the same principle can be applied to more complicated structures that need to be welded.

Controlling Expansion and Contraction

Whenever heat is directed on a metal section, expansion and contraction forces have a tendency to distort or buckle the metal. This is especially noticeable when welding long sections of thin, sheet-metal pieces. The action of these forces may be controlled to some extent by resorting to various techniques such as more uniform distribution of heat, minimizing the amount of heat input, the use

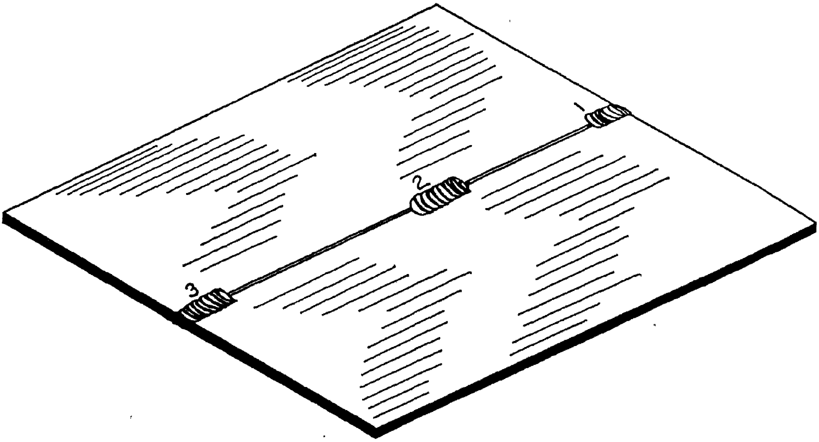


Fig. 58. Stagger Welding

of special jigs, or by providing a space between the edges of the sections to be welded. In many cases the utilization of one or all of these controls may be necessary, depending on the nature of the welding job.

By a more even heat distribution is meant the application of heat over the entire section of the metal before any actual welding takes place. Preheating the pieces in this manner will liberate all the stored-up forces, permitting a more uniform contraction movement when the welding operation is completed.

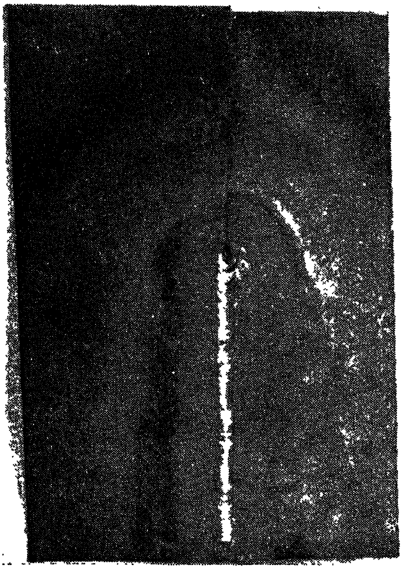


Fig. 59. Improper Space Allowance Causes Edges to Overlap

Controlling the amount of heat input is somewhat more difficult for the beginner. An experienced welder is able to join two seams with the minimum amount of heat necessary for proper fusion. This naturally requires a rapid weld to prevent the metal sections from absorbing an excessive amount of heat. A technique often employed to minimize the heat input is the so-called stagger weld. In this method the operator welds a short distance at the beginning of the joint, next applies the welding for a few inches at the center of the seam, and then moves to the end of the seam. Finally he comes back to where the first weld ended and proceeds in the same manner, repeating the cycle until the weld is completed. This operation greatly counteracts buckling and minimizes any tendency toward cracking, especially in welding metal of low ductility.

The use of jigs will alleviate to an appreciable extent any distortion, since holding the metal in a fixed position prevents any excessive movements. By a jig is meant any device that will hold the metal sections rigidly in position during the welding operation. These jigs may consist of nothing more than a few C clamps to hold

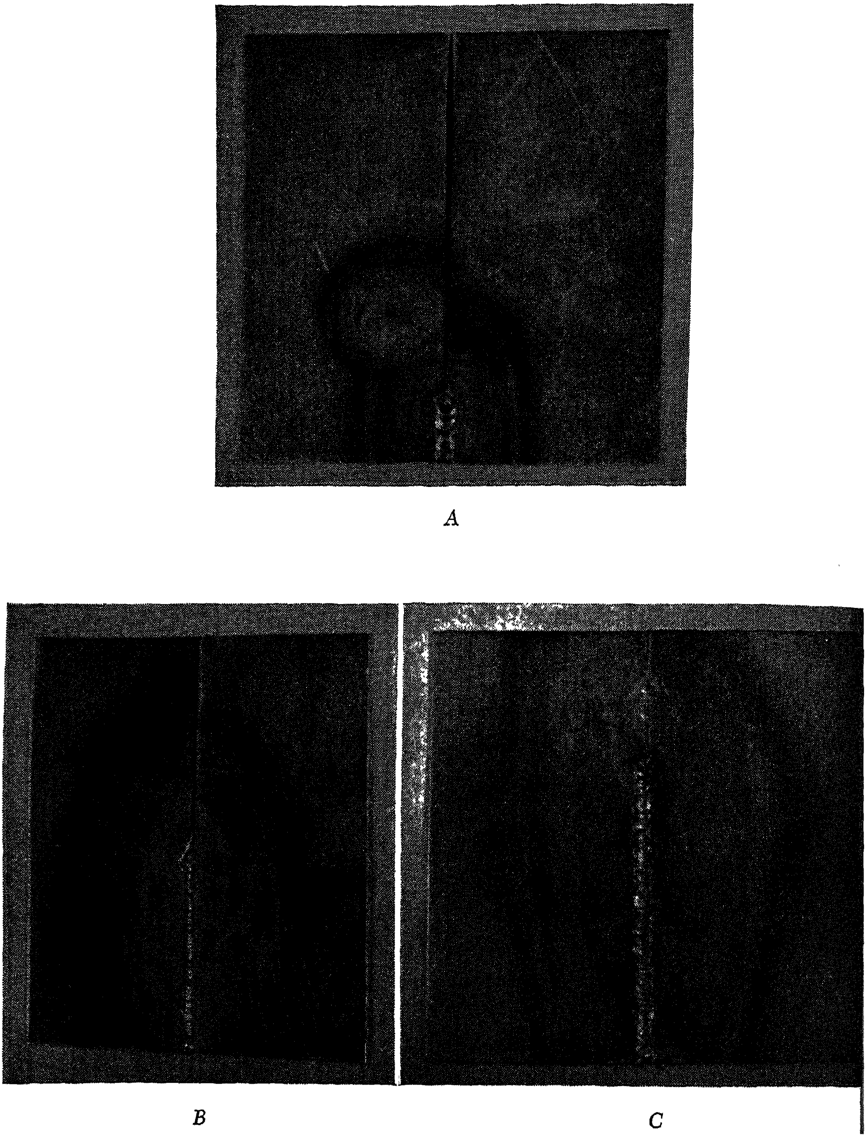


Fig. 60. Proper Spacing Gradually Draws Pieces Together

down the metal, or they may be somewhat elaborate affairs for production purposes.

The proper spacing of the pieces will prevent a certain amount of distortion. It will be found that if two sections are placed together with very little space between them, the edges will gradually overlap as the welding progresses. A practice followed by the average welder is to allow a space between the pieces equal to the thickness of the metal for every foot in length.

QUESTIONS

1. What is the difference between expansion and contraction?

2. Why are expansion and contraction important factors to consider in welding?

3. How may distortion of welded sections be minimized?

4. What effect will preheating have on expansion and contraction forces?

5. What is meant by stagger welding?

6. What is the generally accepted rule for space allowances?

Unit 19

WELDING HEAVY STEEL PLATE

IF YOUR PREVIOUS WELDS have been satisfactory you are now ready to attempt welding heavier metal. When metal is thicker than ⅛″ the edges must be beveled to a 45-degree angle before welding. Place the two beveled edges together to produce a groove of 90 degrees, which must be filled with metal. See Fig. 61. Unless the edges are cut to approximately this angle, it is practically impossible to secure proper penetration.

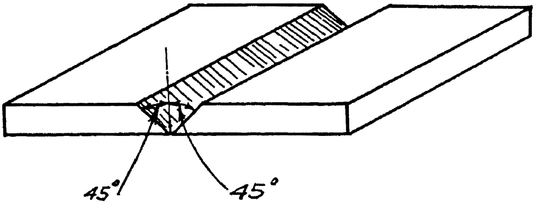


Fig. 61. Plates Beveled for Welding

Practice Weld 1

Secure two ³⁄₁₆″ or ¼″ plates and bevel the edges to 45 degrees. With the proper-sized rod, fill in the bevel groove. Make sure that both sides of the base metal are in a molten state before adding filler rod. Build up the weld about ¹⁄₁₆″ above the surface of the plates. A semicircular or a continuous torch motion may be used to weld heavy plate. The rod also should be moved in a similar motion, but its direction of travel should be opposite to that of the torch.

Practice Weld 2

When you are able to properly weld ³⁄₁₆″ and ¼″ metal, practice welding ⅜″, ½″ and ¾″ plates. In welding these plates it will be necessary to build up the weld in layers, as it is difficult to control the molten puddle in filling the vee in one lap. After the first weld is made the second layer is put on; it is very important that the second or third layer be fused in the preceding layer and sides of the vee. Plates that are thicker than ½″ should be beveled on both sides. See Fig. 62.

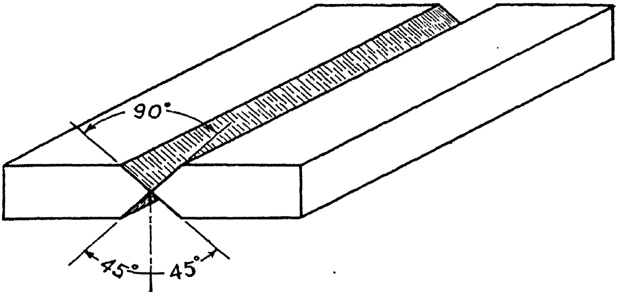


Fig. 62. Plates Showing Bevel on Two Sides

QUESTIONS

1. Why is heavy metal more difficult to weld than light metal?
2. Why is it necessary to bevel the edges of heavy plate?
3. What sized tip should be used to weld ¼″, ⅜″, ½″ and ¾″ metal?
4. What working pressure should be used for welding these plates?
5. Why should the weld be built up in layers in the vee?

Unit 20

CAST-IRON WELDING

GRAY CAST IRON may be fused so that the weld is of the same material as the base metal or it may be bronze welded. The latter method will be described in the next lesson.

To weld cast iron, the metal must be preheated in order to equalize the expansion stresses. As was previously mentioned, gray cast iron is brittle and very susceptible to changes in temperature. If the temperature in the casting is not even the metal will crack. Small cast-iron pieces may be preheated with the torch, while large castings must be placed in a preheating furnace. After the welding has been completed, it is very important that the metal be cooled slowly.

Each joint of the casting to be welded must be beveled to a 45-degree angle. To insure a good, sound weld it is necessary to clean the surface around the seam from all rust, dirt, grease, etc. These impurities, if not removed, will enter the molten metal, leaving numerous pores in the weld.

Welding Procedure

In order to weld cast iron, it is essential to use a good cast-iron rod having the same properties as the base metal. A cast-iron flux is also needed for this type of welding.

Secure two pieces of gray cast iron, bevel the edges, and clean the surface around the joint. Slowly heat the entire piece of metal to a dull red. Place the end of the cast-iron rod near the flame to heat it slightly. Then dip the rod into the can of flux. Since the flux will adhere to the heated rod, this will introduce the flux into the molten puddle. See Fig. 63. Never sprinkle the flux over the molten metal.

The torch should be constantly moved in a circular motion to distribute the heat as evenly as possible. Keep the cone of the flame about ⅛″ away from the metal, and melt the sides of the vee so that the metal flows into the bottom of the groove. When the sides begin to break down, dip the tip of the rod in the puddle and keep it there. The heat of the puddle will be sufficient to melt the rod; never keep dipping the rod in and out of the puddle. As the rod melts, the molten metal will rise in the groove. When it has been built up slightly above the top surface move the puddle forward. Extreme care must be taken to avoid moving the molten metal before the sides of the vee have been broken down, as this would force the molten puddle ahead on the cold metal. From time to time stir the puddle, and, if there is any dirt, etc., floating on the top of the molten metal, skim off the impurities with the rod.

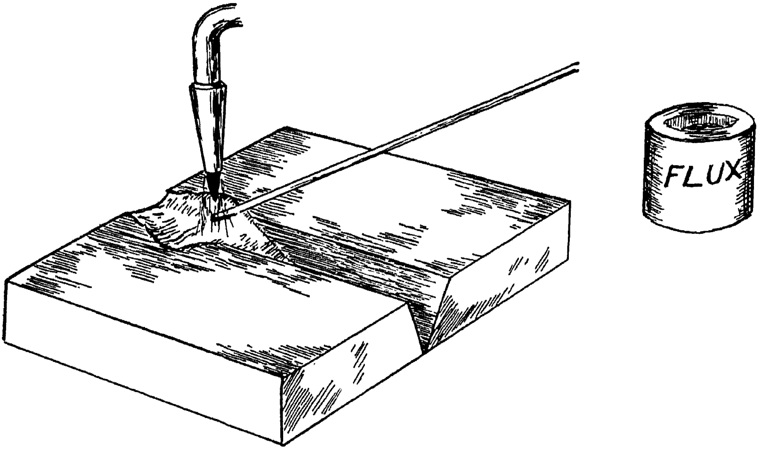


Fig. 63. Cast-Iron Welding

Testing the Joint

After the piece of cast iron has been cooled, place it in a vise and strike it with a hammer until the piece breaks. If the metal has been welded properly, the break should not occur in the fused section, but in the base metal.

QUESTIONS

1. Why should a rod having the same properties as the base metal be used for this type of welding?

2. Why should cast-iron pieces be preheated before welding?

3. What is the purpose of a preheating furnace?

4. Why should welded cast-iron pieces be cooled slowly?

5. How should the joint of castings be prepared for welding?

6. How should the rod be introduced to the puddle?

7. What precaution should be taken in moving the puddle forward?

8. If the metal has been properly welded, where should the break occur when tested?

Unit 21

BRAZING OR BRONZE WELDING

THERE ARE MANY KINDS of metal, such as cast iron (gray and white), malleable iron, nickel, copper, brass, and dissimilar metals (cast iron and steel, etc.) that can be joined together much easier by bronze welding. Bronze welding is a process of flowing molten bronze over the heated surfaces of metal to be joined, furnishing a solid bond between the two seams.

The advantage of bronze welding results from the fact that the metal to be welded need not be heated to a molten state. The surfaces are simply heated to a cherry red. This is particularly important in joining those metals that lose their physical properties when melted, such as malleable iron and heat-treated steels. Bronze welding also simplifies the welding of those metals that ordinarily must be preheated before being fused.

The one precaution that needs to be considered in bronze welding is not to bronze-weld a metal that will be subjected to a high temperature later, since bronze loses its strength when heated to a temperature of 500 degrees F. or more.

Welding Procedure

On heavy metals, the edges should be beveled, as in welding steel and cast iron. The surrounding surface must be cleaned from all dirt, rust, etc. A bronzing rod and bronzing flux must be used to insure a good union between the base metal and the bronze. The flame should be slightly oxidizing with the torch moving in a slight semicircular motion.

Heat the surface of the base metal to a cherry red. When the temperature of the metal is correct, heat the bronzing rod and dip it in the can of flux. Sufficient flux will adhere to the rod without having to sprinkle any of the flux over the surface of the metal. Bring the rod near the tip and let the molten bronze flow over a small area of the seam. Build this surface up to the required height and then move the torch forward, repeating the same process.

The base metal must be of the correct temperature; otherwise, if the metal is too hot the bronze will boil and form drops which roll off as fast as the bronze is applied. If the metal is not hot enough the bronze will refuse to flow smoothly. Continue to add flux as the weld progresses forward. When the weld is completed allow the metal to cool slowly.

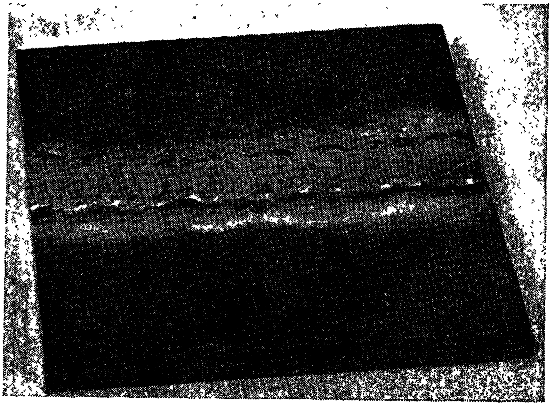


Fig. 64. Bronze Weld

Practice Welds

Practice bronze welding by running a series of beads on a piece of scrap steel. When you have developed the knack of depositing the bronze rod, weld a number of butt, lap, and tee joints. This is to be done on 1/8″ steel plates, to be followed on 1/4″ to 1/2″ metal.

Next, bronze-weld a number of cast-iron pieces, and, when you have sufficiently mastered this exercise, practice joining pieces of cast iron and steel.

QUESTIONS

1. How does bronze welding differ from a regular, fusion weld?

2. What metals may be bronze welded?

3. What particular advantage does bronze welding have over fusion welding?

4. Why is it not advisable to bronze-weld metal that is subjected to intense heat?

5. How should the joint for bronze welding be prepared?

6. How hot should the base metal be heated for bronze welding?

7. How should the torch be manipulated for this type of welding?

8. What happens if the temperature of the base metal is incorrect?

Unit 22

PIPE WELDING

WITH NUMEROUS DEMANDS for pipes to carry oil, water, steam, etc., welding has been found to be the most satisfactory means of joining sections of pipes for these purposes. Welded pipes offer considerable advantages over screw joints because a more permanent joint can be secured; a leak is less likely to occur, and sections of pipes can be fastened together with greater ease.

One-piece construction, secured by means of welding instead of fittings, has a number of practical advantages. Probably the most important feature is the fact that welded piping is leakproof. When two pieces of pipe have been fused together there is nothing to work loose. The weld is a solid part of the pipe wall itself and will last as long—in fact, can be made to last longer. This means that costly repair bills caused by leaking joints are practically eliminated. In many cases, the saving of repair bills is of minor importance compared to the saving of possible damage to equipment or merchandise, which may result from leaking joints. There is another interesting advantage, which appears when the probability of wanting to make changes in the pipe line is considered. This would seem to be a serious problem in a welded line when so much has been said about its permanent character. It happens, however, that the welded line lends itself very easily to alteration, the cutting torch being used to remove any part which is not desired and to prepare the connections for new portions which are being added, everything else being left in place. This is a great contrast to the amount of work involved in making changes in lines where mechanical joints are used. Similar advantages appear when alterations are made in a building plan during the course of construction. Such alterations are very costly if a number of special fittings have been ordered and made to specification for a given job, but when the line is being welded, a few notes of instruction to the contractor will enable him to change his procedure to fit the new plan without any additional cost for new materials and without any delay in waiting for them to arrive.

When the matter of strength is considered, the properly welded line is much superior to the line assembled by means of fittings. For example, it is obvious that in order to make use of a screw fitting, the pipe wall is reduced in thickness at the joint by cutting the threads. Therefore, the weakest part of the line is at the joint, where part of the material has been cut away. The welded joint, on the contrary, can easily be made stronger than the pipe itself, thus making the connection the strongest part of the line instead of the weakest part. Furthermore, in the case of screwed fittings there is a great deal of excess metal in the main part of the pipe line because it has been necessary to make allowance for weakening it at the joint. This indicates the possibility of using a lighter pipe when the assembly is to be made by welding, and thus accomplish considerable saving in material cost.

The fact that fittings add considerably to the weight of a pipe line and that welded connections do not add appreciably to the weight is of a real importance in many cases where the number of turns and branches would ordinarily call for a large number of heavy fittings. The saving in weight in such cases is accompanied by a saving in space, the welded joint being so much neater and so much more compact that the pipe system occupies less space in the building. If the pipes have to be insulated the welded connections are much easier to cover, and the fact that they are leakproof eliminates the possibility of having to tear away the insulating material for repairs.

There are some lines in which the matter of easy flow becomes important when the completed installation is put into service. It may require a great deal of additional expense, if fittings are used, to construct the line so that there will be the least possible obstruction to the flow, but in planning a welded line it is easy to take care of this matter without increasing the installation cost on either material or labor.

Pipe Joints

Welding was not adopted as a satisfactory method of joining pipe until all kinds of tests had been used to prove that welded connections met every requirement of the pipe line installation. In the course of the many investigations which have been made in this field, numerous designs have been used, and the data accumulated in the course of making the tests have served the purpose of demonstrating the efficiency of various types of connections. The general conclusion drawn from these investigations is that the butt weld with the edges of the pipe beveled is the most satisfactory joint as a general rule.

It has been the practice of some pipe fitters who approach the subject of welding rather timidly, to follow the procedure of using an ordinary screwed fitting and then running a fillet weld around each edge of the fitting. This is probably the least satisfactory method of using welding on pipe work. In the first place, it is not the strongest joint which can be made by welding, because the pipe has already been threaded and is consequently weakened by that operation. Another objectionable feature to it is that two welds are required for each connection. A third serious objection is that when this practice is followed the cost of making a joint is very high because to the welding cost there is added the entire cost of furnishing the coupling and installing it. Sometimes a pipe line which is leaking badly at a

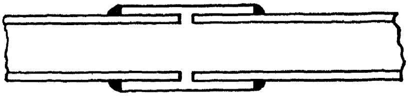


Fig. 65. Welded Screw Coupling

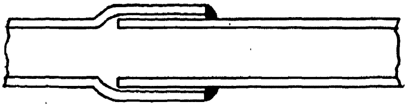


Fig. 66. Bell and Spigot Joint

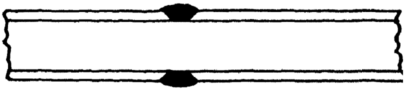


Fig. 67. Butt Joint

coupling can be repaired by welding in this manner, but it probably would be better practice to cut out the entire coupling and insert a plain piece of pipe, making two good butt welds. There is certainly nothing gained by putting in a new line with couplings welded in this manner.

Another type of joint which has been tried and on which some tests have been made is the bell and spigot type of joint illustrated in Fig. 66. This is a familiar design and one which enables a line joint to be made by means of a single weld. Sometimes this design is advantageous when the pipe is in a vertical position, and on some kinds of large diameter work it has been favored to some extent because of the apparent ease of lining up the joint. However, this involves special preparation of the pipe, which increases the cost of the installation without adding anything to the strength or security of the line. Some experiments have been made to see whether additional strength is secured by drilling a number of holes in the belled portion of the pipe, which can be filled up by welding from the outside so that the deposited metal has about the same function as the rivet has. This would appear to give a more secure joint, but actual tests on full size joints show conclusively that failure and breakage always occur at the rivet tacks, well below the strength of a butt-welded joint.

Fig. 67 is a sketch of the familiar butt weld in pipe with beveled ends. With this design it is not difficult at all to make the joint fully as strong as the rest of the pipe, if not stronger. It is the simplest and most efficient design from the standpoint of the welder, offering the greatest opportunity for getting complete penetration and for providing sufficient reinforcement to give all the strength required. Furthermore, it puts the weld metal directly in line with the lines of force so that when any pull is exerted on the pipe there is no dangerous concentration of stresses at any point. (Where pipe lines are apt to be subjected to extraordinary stresses it is sometimes advisable to strengthen the joint by welding on reinforcing plates across the weld, but these cases are comparatively rare.)

Beveling Pipe With the Torch

Whenever the building specifications call for welding of a pipe line, the pipe which is supplied will usually have the ends already beveled in preparation for the standard form of butt weld. However, a good many of the standard lengths of pipe will have to be cut into odd lengths in order to meet the requirements of the complete specification, and where these odd lengths are cut off they will have to be beveled. The most economical way to do this is with the cutting torch. Some beveling will also be necessary whenever odd angle connections and special fittings, branches or bends, are made up on the job. When the pipe is being beveled with the cutting torch, it must be remembered that it is advisable to leave a slight amount of the end of the pipe unbeveled so as to assist in getting a good alignment while setting up the joint and to reduce the liability of melting through too far on the inside wall and thus leaving a certain amount of obstruction. If the cutting is done by holding the torch on the outside of the pipe so that the flame is directed toward the inside, it is a little difficult to control the cut so as to leave an unbeveled portion of uniform width. It will be found easier to reverse the position of the torch, holding it toward the inside of the pipe with the flame directed toward the outside wall while making the bevel. In this manner the operator has a good view of the unbeveled portion and can hold this to a more uniform dimension.

Expansion and Alignment

Every gas welder will remember that his very first practice welding exercises made him acquainted with the phenomena of expansion and contraction—how they caused sheets to separate, then draw together while being welded—and what precautions it is necessary to take to prevent the metal in the vicinity of the weld from becoming warped or buckled. The pipe welder must bear in mind that expansion occurs in the metal when pipe is being welded and can naturally expect that some difficulties will be encountered unless precautions are taken to offset these difficulties.

1. Spacing pipe:

It has been found that this can be handled by allowing a little space between the ends of the pipe lengths which are being butt-welded together. On the small sizes of pipe, that is, up to 2 inches, the amount of metal involved is so small and the pipe wall is so light that only a small separation is necessary—in fact, just enough to make sure that fusion can be secured all the way to the inside wall of the pipe. In these small sizes the pipe is very often welded without beveling. For 3″ pipe, however, it is advisable to leave a space of about 3/32″ between the butted ends of the pipe. When diameters of from 4″ to 6″ are involved, the spacing should be about 1/8″, and for everything over 6″ it is considered good practice to increase the space to 3/16″ between the edges.

2. *The purpose of clamps:*

The reason for using clamps in pipe welding is a matter of preparation; that is, they serve the purpose of holding the two lengths of pipe in perfect alignment and spaced at the proper distance. After the two lengths have been tacked firmly into position as described in the paragraph which follows, there is no further need of the clamp; so it is removed in order that it may not interfere with the proper manipulation of the rod and torch while the weld is being made.

3. *How to make a clamp for pipe welding:*

Fig. 68 shows how to make a clamp for keeping pipe in alignment. The materials used here are pieces of ordinary strap iron and a few common 5/8″ bolts. The advantage of this type of clamp is that it is heavy and rigid enough to hold the pipe in good alignment, and at the same time there is enough space between the parallel, 1½″ straps to allow plenty of room for the welder to do the preliminary tacking. The use of this clamp can be supplemented by the one shown in Fig. 69. This is designed to draw the ends of pipe together if they happen to be set up too far apart. The two outside bands are fastened very tightly to the end of the pipe, and the 5/8″ rods, in this case, are fitted with nuts so that the ends of the pipe can be drawn together by tightening up the nuts. In some cases, where difficulty is being experienced in getting the pipe together, this device is put on over the clamp so that the clamp can be tightened just as soon as the proper spacing has been secured between the ends of the pipe.

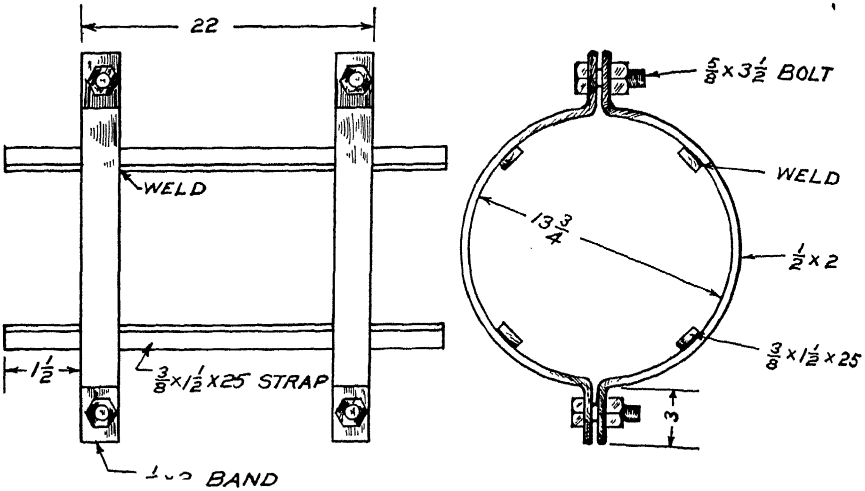


Fig. 68. Clamp for Keeping Pipe in Alignment

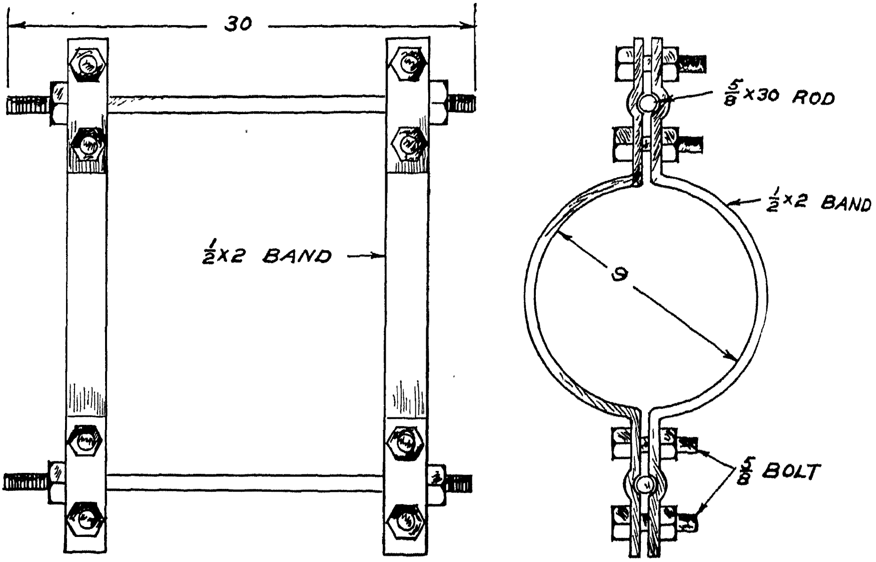


Fig. 69. Clamp for Drawing Ends of Pipe Together

4. *Tacking:*

It is rather difficult to design a clamp which will control the position of the pipe while the final welding is going on, and for this reason it is necessary to tack the two lengths of pipe in position by making short welds at intervals around the circumference. For the small pipe, three tacks are usually sufficient, and for the medium sizes, four or five will take care of it. For very large pipe, that is, 12″ in diameter and over, it is always advisable to use enough tack welds so that they will not be spaced more than 7″ or 8″ apart. Where tack welds are being made on the large diameter pipe, it is good practice to have two welders working at the same time and have them making their tack welds on opposite points on the circumference; but where this is not possible, a single operator can do a satisfactory job by working back and forth across the circumference of the pipe.

These tack welds need be only about 1″ long and should not be reinforced. After the tack welds are made, the clamp can be removed and the welder can proceed to make the complete joint. It is necessary to weld completely through each tack instead of simply running the weld over it.

It is particularly important that beginners in pipe welding should pay careful attention to spacing, clamping, and tacking pipe in position in their practice exercises. These exercises are generally performed with short lengths of pipe, and the effects of expansion and contraction are not so obvious as they will be in the field when the welder starts working on standard lengths.

Templates for Cutting Pipe

The majority of welds made in field pipe installations will be plain butt welds in straight lengths of pipe. However, there are a number of cases in each installation where a change in the direction of the pipe is necessary. Sometimes these changes are made by the use of special fittings, and in other cases it is necessary to cut pipe at various angles to make turns. It is also necessary to make various angle and tee connections for branch lines. The simplest way to prepare the pipe for these various types of connections is to have a template made of heavy paper, or of light sheet metal, which can be wrapped around the pipe and the line of cut traced with a piece of soapstone. The pipe is then cut with the cutting torch and the beveling is done, also with the cutting torch. Before starting to weld on pipe which has been prepared in this way, it is, of course, necessary to remove all scale by chipping and brushing with a wire brush.

The preparation of templates involves the solution of a series of problems in descriptive geometry. These solutions have been worked out to cover practically all types of pipe connections, but it is not necessary for the welder to study the theory of making the proper curves for these templates. Those most ordinarily used can be made by following a few simple directions, and the most difficult ones can usually be supplied by sheet metal workers who are accustomed to turning out patterns of all kinds.

Illustrations and tables have been prepared to show how to make templates for some of the simplest types of connections.

For example, Fig. 70 shows three curves which are used in making turns of 90 degrees, 45 degrees, and 30 degrees respectively. Fig. 71 shows a two-piece, 90-degree turn in which one weld is required. Fig. 72 shows a 90-degree turn made with three pieces, requiring two welds. In this case, it can be seen how the same curve can be used to cut pipe so as to make a 45-degree angle with one weld. Similarly, Fig. 73 shows a 90-degree turn made up of four pieces and requiring three welds. The illustration indicates how a 30-degree turn could be obtained with one weld and a 60-degree turn with two welds.

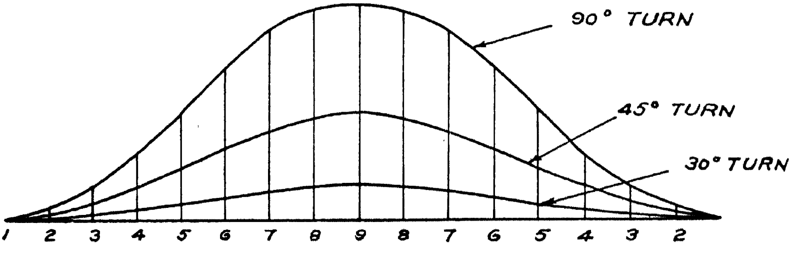


Fig. 70. Curves for 30°, 45°, and 90° Turns

Returning now to the set of curves shown in Fig. 70, it will be seen that each complete curve can be made by connecting with a smooth curve certain points on the vertical lines. These vertical lines are called "ordinates."

All who have made or used pipe templates have undoubtedly noticed that templates for various sizes of pipe with the same angle of turn have the same general shape, differing only in size. In fact, an exact proportion does exist. This fact makes it possible to calculate tables which will cover patterns for different angles for various sizes of pipe.

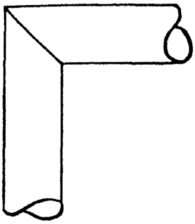


Fig. 71. Two-Piece 90° Turn—One Weld

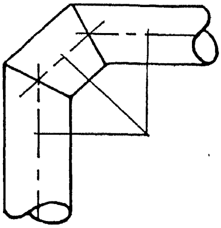


Fig. 72. Three-Piece 90° Turns—Two Welds Make Two 45° Turns

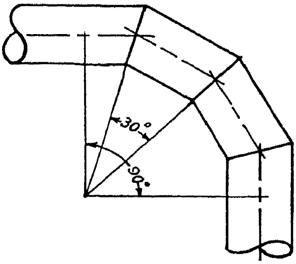


Fig. 73. Four-Piece 90° Turns—Three Welds Make Three 30° Turns

To construct the curve for a template, draw a base line equal to the circumference of the pipe. Table II gives the circumference of pipe of various diameters, together with the thickness of the pipe wall. The curve of the template is laid out from the base line, using sixteen ordinates to locate the different points on the curve. The distance between the ordinates is also given in Table II. In Fig. 70 the ordinates for the left half of the curve are designated by the numbers 1 to 9, 9 being the ordinate at the center of the curve. These are all the ordinates that are required in making the curve, because the right half can be laid out by using the same ordinates and starting from the right end.

The length of each of these ordinates bears a certain relationship to the circumference, which can be expressed as a ratio. For example, ordinate 9 for a 90° turn is equal to the circumference multiplied by 0.318. This holds true for any circumference for that ordi-

TABLE II

NOMINAL PIPE SIZE *Inches*	THICKNESS OF METAL STD. WT. PIPE *Inches*	CIRCUMFERENCE OF PIPE *Inches*	SPACING OF 16 ORDINATES *Inches*
2	5/32	7 15/32	15/32
2 1/2	13/64	9 1/32	9/16
3	7/32	11	11/16
3 1/2	1/4	12 9/16	25/32
4	1/4	14 1/8	7/8
4 1/2	1/4	15 23/32	31/32
5	17/64	17 15/32	1 3/32
6	9/32	20 13/16	1 5/16
7	5/16	23 31/32	1 1/2
8	11/32	27 3/32	1 11/16
9	11/32	30 1/4	1 7/8
10	3/8	33 25/32	2 1/8
12	3/8	40 1/16	2 1/2
14	3/8	43 31/32	2 3/4
15	3/8	47 1/8	2 15/16
16	3/8	50 1/4	3 5/32
18	3/8	56 9/16	3 17/32
20	3/8	62 27/32	3 15/16

TABLE III

90° BENDS ONLY

FOR ORDINATE NO.	MULTIPLY CIRCUMFERENCE OF PIPE BY ORDINATE FACTOR	FOR ORDINATE NO.	MULTIPLY CIRCUMFERENCE OF PIPE BY ORDINATE FACTOR
1	0.0	6	0.22
2	0.012	7	0.272
3	0.047	8	0.306
4	0.098	9	0.318
5	0.159		

nate, so that after measuring the circumference of a piece of pipe, ordinates for a 90-degree turn of any diameter can be calculated by multiplying by the factors given in Table III.

Table III gives the complete set of ordinate factors for a 90-degree turn. The use of the table may be illustrated by constructing a template for a 45-degree cut on a 6″ pipe. First cut a strip of stout paper, perhaps 12″ wide and long enough to wrap around the pipe. This length is given in Table II under the column headed "Circumference of Pipe" and is found to be 20¹³⁄₁₆″. This distance is then divided into sixteen equal spaces, and perpendicular lines or ordinates are erected. This spacing is also given in Table II, and is found to be 1⁵⁄₁₆″. Now rule a straight line somewhat below the center of the paper, and, about 4″ below this line, rule another, parallel to it. Multiply the length of the base line (20¹³⁄₁₆″) by the factors in Table III and lay off these values on the ordinates, starting at one end. The calculations are indicated in Example 1. For convenience in multiplying, fractions of an inch can be converted into decimals. Table V gives these decimal equivalents at intervals of ¹⁄₃₂″.

When all the ordinates have been measured, draw a smooth curve through the points; then cut the strip along the curve and along the straight line which has been drawn a few inches below the base line. To use the template, wrap it around the pipe, putting the longest ordinate (9) at the point where the extreme outer end of the elbow is desired. Trace off the curve on the pipe with a piece of soapstone and make the proper cut by following this line with the cutting torch. Note that the pattern material below the base line is necessary to give body and stability to the template while it is being used, and, in wrapping about the pipe, both extremities of template must coincide.

EXAMPLE I

Template for 90 degree turn, in 6″ diameter pipe.
Circumference of pipe from Table II equals 20.81″.

Ordinate	Circumference		Ordinate Factor
1	20.81	x	0.0 = 0.0 or 0″
2	20.81	x	0.012 = 0.25 or ¼″
3	20.81	x	0.047 = 0.98 or 1″
4	20.81	x	0.098 = 2.04 or 2″
5	20.81	x	0.159 = 3.31 or 3⁵⁄₁₆″
6	20.81	x	0.220 = 4.58 or 4⁹⁄₁₆″
7	20.81	x	0.272 = 5.66 or 5¹¹⁄₁₆″
8	20.81	x	0.306 = 6.37 or 6⅜″
9	20.81	x	0.318 = 6.62 or 6⅝″

TABLE IV

FACTORS FOR OTHER ANGLES

FOR ANGLE OF TURN EQUAL TO	MULTIPLY CIRCUMFERENCE OF PIPE BY	REMARKS
80 deg.	0.839	
70 deg.	0.700	
60 deg.	0.577	
50 deg.	0.466	
45 deg.	0.414	Two welds per 90 deg. turn.
40 deg.	0.364	
30 deg.	0.268	Three welds per 90 deg. turn.
22½ deg.	0.198	Four welds per 90 deg. turn.
20 deg.	0.176	
10 deg.	0.087	

TABLE V

DECIMAL EQUIVALENTS OF FRACTIONS

1/32=0.031
1/16=0.063
3/32=0.094
1/8=0.125
5/32=0.156
3/16=0.188
7/32=0.219
1/4=0.250
9/32=0.281
5/16=0.313
11/32=0.344
3/8=0.375
13/32=0.406
7/16=0.438
15/32=0.469
1/2=0.500
17/32=0.531
9/16=0.563
19/32=0.594
5/8=0.625
21/32=0.656
11/16=0.688
23/32=0.719
3/4=0.750
25/32=0.781
13/16=0.813
27/32=0.844
7/8=0.875
29/32=0.906
15/16=0.938
31/32=0.969

The paper template may be used directly if only a few cuts are to be made. If it is thought that more cuts of the same joint will be required at future times, it is worth while to use a much heavier paper, or even thin sheet metal, for the template, so that it will last longer.

Note that Table III gives the multiplication factors for 90-degree turns *only* and that an additional factor is necessary when making turns of other angles. These additional factors are given in Table IV. Example 2 shows the method of using Table IV in conjunction with Table II, the problem in this case being to produce a template for a 30-degree turn in 8″ diameter pipe.

EXAMPLE 2

Template for 30 degree turn, in 8″ diameter pipe.
Circumference of pipe from Table II equals 27.1″.
For 30 deg. turn multiply 27.1 x .268 (From Table IV) = 7.26.

Ordinate 1—7.26 x 0.0 = 0.0 or 0″
2—7.26 x 0.012 = 0.09 or $\frac{3}{32}$″
3—7.26 x 0.047 = 0.34 or $\frac{11}{32}$″
4—7.26 x 0.098 = 0.71 or $\frac{23}{32}$″
5—7.26 x 0.159 = 1.15 or 1$\frac{5}{32}$″
6—7.26 x 0.220 = 1.60 or 1$\frac{19}{32}$″
7—7.26 x 0.272 = 1.98 or 2″
8—7.26 x 0.306 = 2.24 or 2$\frac{1}{4}$″
9—7.26 x 0.318 = 2.33 or 2$\frac{11}{32}$″

To summarize, the general rule for figuring the sixteen ordinates for any turn in any pipe is as follows: Measure the circumference, or look it up in Table II; multiply this by the factor for the desired angle taken from Table IV, and then multiply this product by each of the ordinate factors from Table III in turn, laying the computed distance off on the respective ordinates measured from a base line and properly spaced as indicated in the last column of Table II. The smooth curve connecting these points will be the desired template.

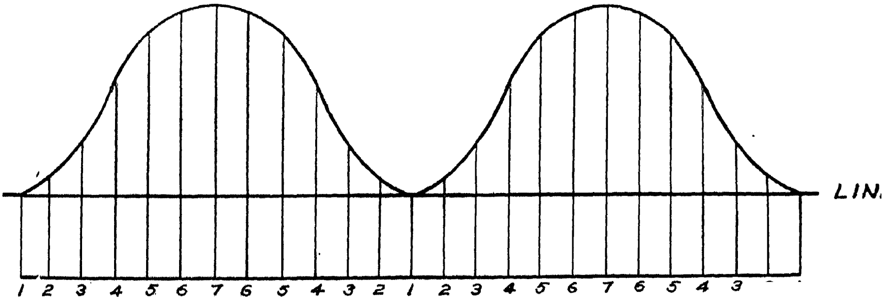


Fig. 74. Template for Tee Connection

Branches

When it is desired to make a tee connection, as for a branch line or in the fabrication of a header, the curve of the template will be of the general shape shown in Fig. 74. To make this pattern, draw a base line as before, divide it into twenty-four parts, and draw an ordinate through each of the twenty-five points. Number these points, as indicated in Fig. 74. Lay off the lengths of the ordinates as given in Table VI. Note that the spacing of the ordinates is also given in this table. Now draw a smooth curve through these points, as shown in Fig. 74, which will give the cutting line for the end of the branch. The branch can then be used for marking the hole in the header or the main. The table does not give dimensions for pipe sizes less than 4″ because in the smaller sizes of pipe it is usually possible to make cuts sufficiently accurate for practical purposes without the use of templates.

Where the branch and header are the same size, the ordinates 7 have been shortened twice the thickness of the pipe wall in order to give a rounded end instead of a point. This should also be considered when a branch is being marked freehand on the pipe.

Cutting Branches Without Templates

It frequently happens in the course of the installation of a pipe line that unexpected changes in the layout make it necessary to construct turns or branches for which templates have not been provided. If there is no time to procure a template for such a connection, Fig. 75 shows a method of cutting pipe which will be found to give a satisfactory fit for most purposes. The two pieces of pipe are set up together at the required angle of the intersection. A straightedge is laid on the branch parallel to it and just resting on the main pipe. Punch marks are made at the points 1 and 1. The

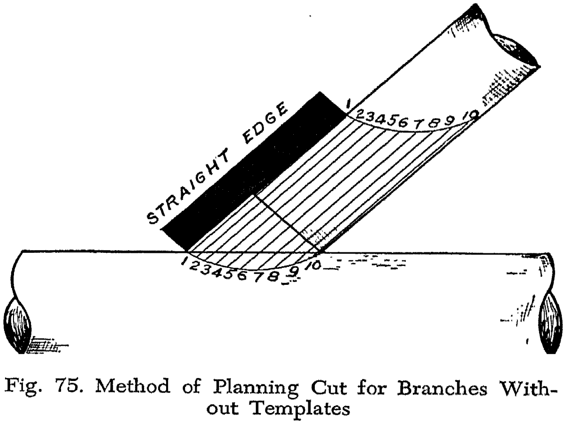


Fig. 75. Method of Planning Cut for Branches Without Templates

TABLE VI

TEMPLATE DATA FOR 90° BRANCH

Dia. of Branch *inch*	Dia. of Header *inch*	Width of Pattern *inch*	Spacing of Ordinates *inch*	Length of Ordinates above Base Line					
				2 in *inch*	3 in *inch*	4 in *inch*	5 in *inch*	6 in *inch*	7 in *inch*
4	4	14 1/8	19/32	3/32	9/32	5/8	31/32	1 3/16	1 3/8
4	6	“	“	1/16	3/16	3/8	9/16	5/8	11/16
4	8	“	“	1/32	3/32	1/4	3/8	7/16	15/32
4	10	“	“	1/32	3/32	3/16	5/16	11/32	3/8
4	12	“	“	1/32	1/16	5/32	1/4	9/32	5/16
4	14	“	“	1/32	1/16	5/32	7/32	1/4	9/32
4	15	“	“	1/64	1/16	1/8	3/16	7/32	1/4
4	16	“	“	1/64	1/32	1/8	3/16	13/64	7/32
4	18	“	“	1/64	1/32	3/32	5/32	11/64	3/16
4	20	“	“	1/64	1/32	3/32	1/8	9/64	5/32
6	6	20 13/16	7/8	1/8	3/8	7/8	1 13/32	1 13/16	2 7/32
6	8	“	“	3/32	1/4	19/32	31/32	1 5/32	1 5/16
6	10	“	“	5/64	7/32	7/16	21/32	25/32	29/32
6	12	“	“	1/16	3/16	3/8	9/16	21/32	23/32
6	14	“	“	1/16	5/32	11/32	1/2	19/32	21/32
6	15	“	“	1/16	1/8	5/16	15/32	17/32	9/16
6	16	“	“	3/64	1/8	9/32	13/32	15/32	17/32
6	18	“	“	1/32	3/32	7/32	11/32	13/32	15/32
6	20	“	“	1/32	3/32	3/16	5/16	3/8	7/16
8	8	27 3/32	1 1/8	3/16	1/2	1 7/32	1 15/16	2 9/16	3 5/32
8	10	“	“	1/8	3/8	13/16	1 1/4	1 9/16	1 27/32
8	12	“	“	3/32	5/16	11/16	1 1/16	1 1/4	1 13/32
8	14	“	“	3/32	9/32	19/32	29/32	1 3/32	1 1/4
8	15	“	“	3/32	9/32	9/16	13/16	1	1 5/32
8	16	“	“	3/32	1/4	1/2	3/4	29/32	1 1/16
8	18	“	“	5/64	7/32	7/16	21/32	13/16	15/16
8	20	“	“	1/16	3/16	3/8	9/16	11/16	25/32
10	10	33 25/32	1 13/32	7/32	21/32	1 9/16	2 15/32	3 1/4	4
10	12	“	“	3/16	1/2	1 5/32	1 27/32	2 1/4	2 21/32
10	14	“	“	5/32	7/16	1 1/8	1 27/32	2 1/16	2 1/4
10	15	“	“	5/32	7/16	31/32	1 1/2	1 3/4	2
10	16	“	“	1/8	3/8	7/8	1 11/32	1 9/16	1 25/32
10	18	“	“	7/64	11/32	3/4	1 5/32	1 11/32	1 17/32
10	20	“	“	3/32	5/16	21/32	1	1 5/32	1 5/16
12	12	40 1/16	1 43/64	1/4	3/4	1 27/32	2 15/16	3 15/16	4 29/32
12	14	“	“	15/64	23/32	1 9/16	2 7/16	3 1/8	3 25/32
12	15	“	“	7/32	21/32	1 7/16	2 3/16	2 11/16	3 3/16
12	16	“	“	3/16	9/16	1 1/4	1 31/32	2 3/32	2 7/32
12	20	“	“	5/32	7/16	31/32	1 1/2	1 25/32	2 1/16
14	14	43 31/32	1 53/64	5/16	7/8	2 1/16	3 7/32	4 3/8	5 1/2
14	15	“	“	17/64	25/32	1 13/16	2 13/16	3 19/32	4 3/8
14	16	“	“	15/64	23/32	1 5/8	2 17/32	3 5/32	3 3/4
14	18	“	“	7/32	5/8	1 13/32	2 5/32	2 19/32	3
14	20	“	“	3/16	9/16	1 1/4	1 29/32	2 1/4	2 9/16
15	15	47 1/8	1 31/32	5/16	15/16	2 1/4	3 9/16	4 3/4	5 29/32
15	16	“	“	9/32	27/32	1 31/32	3 3/32	3 15/16	4 3/4
15	18	“	“	1/4	3/4	1 11/16	2 19/32	3 1/8	3 21/32
15	20	“	“	7/32	21/32	1 7/16	2 3/16	2 5/8	3 1/16
16	16	50 9/32	2 3/32	21/64	31/32	2 11/32	3 23/32	5 1/16	6 13/32
16	18	“	“	5/16	7/8	1 15/16	3	3 13/16	4 9/16
16	20	“	“	1/4	3/4	1 5/8	2 17/32	3 5/8	3 23/32
18	18	56 9/16	2 23/64	3/8	1 3/32	2 5/8	4 3/16	5 3/4	7 3/16
18	20	“	“	11/32	1	2 7/32	3 7/16	4 5/16	5 1/8
20	20	62 27/32	2 39/64	7/16	1 1/4	2 31/32	4 11/16	6 1/2	8 1/8

straightedge is then moved around the pipe in such a manner that it is always kept parallel to the branch and the lower end just touches the main pipe. At regular intervals the end points 2, 3, 4, 5, etc., are marked on both the main and the branch. After the straightedge has been carried completely around the branch in this manner, a smooth curve is drawn with soapstone through the punch marks. This curve will be the line of cut for both the branch and the main pipe. This procedure can be followed when making a tee connection, too, but tee connections are so common that is is advisable to make a good template, from which the line of cut can be marked on the pipe much faster than by the above plan.*

Welding Procedure

There are two general methods for welding pipe, known as the roll and position weld. In the first method, the weld is started approximately one quarter of the way down from the top of the pipe. The torch is held with the tip pointing upward (as in vertical welding) so that the flame is nearly in a direct line with the pipe. The weld is carried up on the pipe to a point slightly below the top, center. When this point is reached, the pipe is given one quarter of a turn and the weld begun where it was left off. This procedure is carried out until the joint is completed.

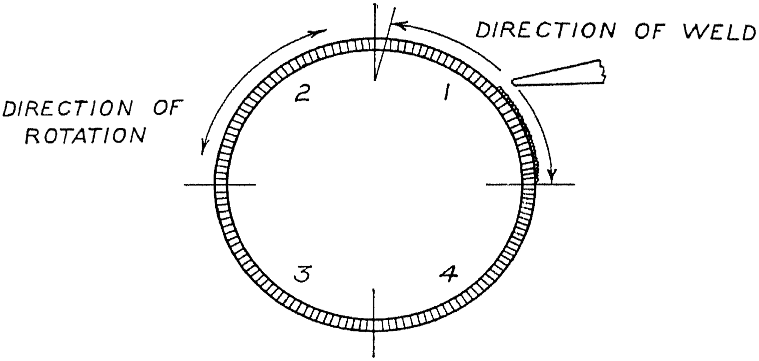


Fig. 76. Pipe-welding Method

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* Reprinted by courtesy of Purity Cylinder Gases.

In the fixed-position weld, the welding is started at the bottom of the pipe and carried up one side until the top is reached. The weld is then again started at the bottom and carried up the opposite side to complete the joint. See Figs. 76 and 77.

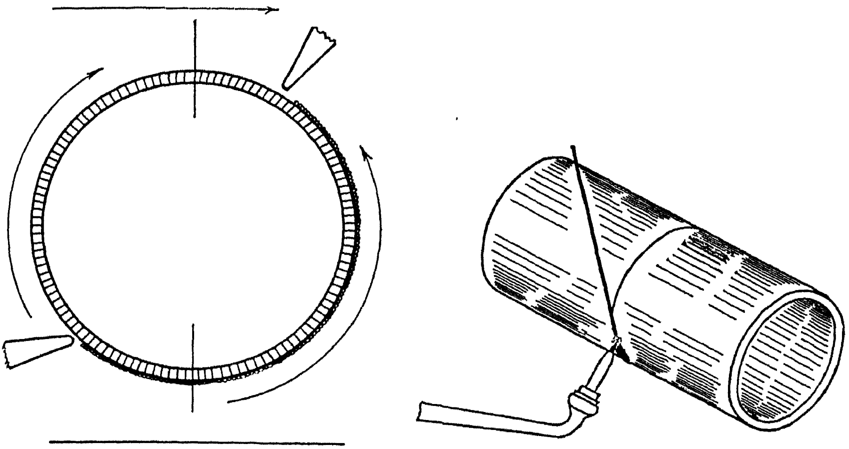

Fig. 77. Torch Position for Welding Pipe

Testing the Weld

Cut the pipe lengthwise into a number of strips. Check the penetration and inspect for any defects. Then place these strips in a vise and bend. Repeat welding until good, strong joints are made.

QUESTIONS

1. What advantages do welded pipe joints offer over screw joints?
2. Why is the butt joint the most satisfactory for welding pipe?
3. When should the edges of the pipe be beveled before welding?
4. Why should the pipes be spaced apart for welding?
5. What is the general practice for space allowance on pipe?
6. Why are clamps essential for welding long sections of pipe?
7. Why are pipes tacked before the welding is started?
8. For what are pipe templates used?
9. Describe two methods that may be used in welding pipes.
10. How should the torch be held for pipe welding?

Unit 23

ALUMINUM WELDING

BEFORE PROCEEDING with aluminum welding, it is well for the beginner to become acquainted with a few of its characteristics in order to better understand the factors involved in welding this metal.

Because of its many useful properties, aluminum has been recognized as a very important metal for the manufacture of countless articles. Aluminum weighs only about one third as much as other commonly used metals; it has a high strength-to-weight ratio, is highly resistant to corrosion, possesses great electrical conductivity, and permits unusual ease in fabrication.

The various kinds of aluminum may be classified into three groups: commercially pure aluminum, wrought alloys, and casting alloys. Each of the latter two may be further divided into non-heat-treatable and heat-treatable alloys.

Commercially Pure Aluminum

This aluminum has a purity of at least 99 per cent, with the remaining 1 per cent consisting of iron and silicon. Since it lacks alloying ingredients, commercially pure aluminum does not possess a very high tensile strength. One of its chief qualities is its ductility, making the metal especially adaptable for bumping, pressing, and forming operations. The two common grades of this group, known as 2S and 3S, are the easiest types of aluminum to weld.

Wrought Alloys

When certain other metals are added to the aluminum, a much stronger alloy is produced. The main alloying elements used are copper, manganese, magnesium, silicon, chromium, zinc, and nickel. These ingredients are added either singly or in combination to produce an alloy possessing definite characteristics. These wrought-alloy materials are made from a cast ingot that has been rolled down to plate, sheet, bar, rod, or other structural shapes. The wrought alloys most adaptable for welding are identified as 51S and 53S.

Casting Alloys

Casting alloys are used to produce aluminum castings, the metal being poured into a sand or permanent metal mold. A great many of the castings are weldable, but extreme care must be exercised when welding the heat-treated types to prevent any loss of the characteristics received by the heat-treating process.

Table VII shows the percentage of alloying elements in wrought aluminum alloys.

TABLE VII

Nominal Composition of Wrought Aluminum Alloys

Alloy	Per Cent of Alloying Elements. Aluminum and Normal Impurities Constitute Remainder								
	Copper	Silicon	Manganese	Magnesium	Zinc	Nickel	Chromium	Lead	Bismuth
2S	....	....	....	....	....	....	....	....	....
3S	....	....	1.2	....	....	....	....	....	....
4S	....	....	1.2	1.0	....	....	....	....	....
11S	5.5	....	....	....	....	....	....	0.5	0.5
14S	4.4	0.8	0.8	0.4	...	....	....	....	....
17S	4.0	....	0.5	0.5	....	....	....	....	....
A17S	2.5	....	....	0.3	....	....	....	....	....
18S	4.0	....	....	0.5	....	2.0	....	....	....
24S	4.4	....	0.5	1.5	....	....	....	....	....
25S	4.5	0.8	0.8	....	....	....	....	....	....
32S	0.8	12.0	....	1.0	....	0.8	....	....	....
51S	....	1.0	....	0.6	....	....	....	....	....
A51S	....	1.0	....	0.6	....	....	0.25	....	....
52S	....	....	....	2.5	....	....	0.25	....	....
53S	....	0.7	....	1.3	....	....	0.25	....	....
56S	....	....	0.1	5.2	....	....	0.1	....	....
70S	1.0	....	0.7	0.4	10.0	....	....	....	....

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Identification System

Due to the number of aluminum alloys, it has been necessary to devise some means for properly identifying them. Such a system is now in existence and uniformally employed for labeling these metals. The wrought alloys are designated by the letter *S*. Preceding this letter a number is used for each alloy to denote its composition, such as *17S*. Following this symbol, additional letters or numbers are used to show the type of temper as well as the manner in which the hardness of the alloy has been obtained.

The non-heat-treatable wrought alloys, such as the *2S*, *3S*, and *52S*, are those that cannot be hardened by any form of heat-treatment; their varying degrees of hardness is controlled only by cold working. The *2S* is the commercially pure aluminum, the *3S* is an alloy containing 1.2% manganese, and *52S* an aluminum having a small percentage of magnesium and chromium. The following markings are used to show their hardness:

2S-0 = dead soft (annealed)
¼h = one-quarter hard
½h = one-half hard
¾h = three-quarters hard
H = hard

The heat-treatable wrought alloys are those whose hardness and strength are further improved by subjecting them to various heat-treating processes.

The following are the symbols used after the code number to express the hardness:

17ST—the *T* indicates that the alloy is in its full heat-treated and age-hardened condition.
W—indicates an alloy that has been subjected to the regular heat-treating process but has not been artificially aged (used only for alloys that require artificial aging). Some alloys obtain their full strength only after they have been aged by keeping them at a certain temperature for a definite period immediately following the heat-treating process.
RT—an alloy that is in its full heat-treated condition and also has been strain-hardened, that is, cold worked, usually by rolling, to produce still greater strength values.

The casting alloys are indicated by a number—for example, *214*. When a letter precedes the number, it shows a variation in the composition from the original alloy. This slight change in the composition is simply to impart some desirable characteristic. Thus, in the cast alloy 214 a slight amount of zinc may be added to increase its pouring qualities and then this alloy is labeled *A*-214.

Welding Characteristics

Learning to weld aluminum is not difficult after one has become familiar with the behavior of this metal under the welding flame. The following are some of the characteristics that must be considered when welding aluminum:

1. Non-heat-treated aluminum, especially in the pure grades, has a very low melting point, somewhere around 1215° F.

2. The thermal conductivity of aluminum is exceptionally high, being almost four times that of steel.

3. Due to its light color, there is practically no indication when the melting point is reached, for when the metal begins to melt it collapses suddenly.

4. Molten aluminum oxidizes very rapidly, forming a heavy coating on the surface of the seam, which necessitates the use of a good flux.

5. Aluminum when hot is very flimsy and weak and care must be taken to support it adequately during the welding operation.

Flux

The most important step in welding aluminum is to clean thoroughly the edges that are to be joined. A wire brush or steel wool should be rubbed over this area until a dull-white, nonreflecting surface is secured.

Since all aluminum oxidizes very rapidly, a layer of flux must be used to insure a sound weld. The flux is sold as a powder, which is usually mixed with water to a consistency of a thin paste (approximately two parts of flux to one part of water).

If the welding does not require the addition of any filler rod, the flux is applied to the joint by means of a brush. When a filler rod is used, the rod also is coated with flux. On heavy sections it is advisable to coat the metal as well as the rod for greater ease in securing better fusion.

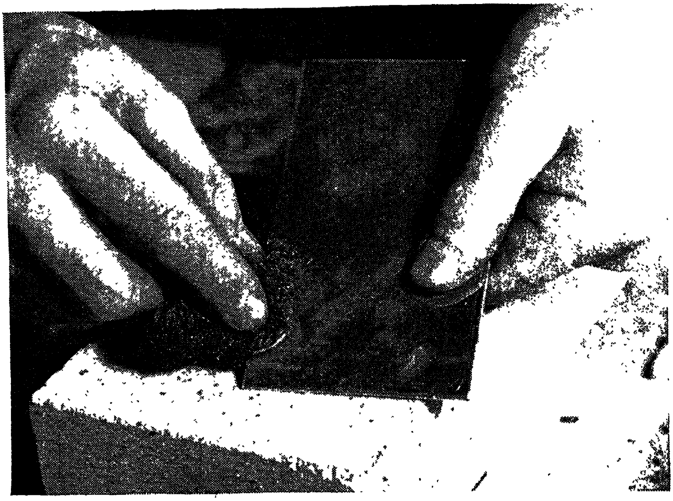

Fig. 78. Cleaning the Edges

When the welding has been completed it is very important that all traces of the flux that may adhere to the surface be washed away. Otherwise, the remaining flux will subsequently cause corrosion. The flux is removed by washing the piece in hot water or by immersing the weld in a 10-per-cent cold solution of sulphuric acid.

Welding Rod

As in welding other metals, the proper selection of a filler rod is important for properly welding aluminum. The composition of the rod should compare to that of the metal to be welded. In the non-heat-treated 2S and 3S, the weld should be made with a 2S wire. A rod consisting of 5 per cent silicon and 95 per cent aluminum is recommended for welding the alloys 51S and 53S.

Welding rods are obtainable in sizes of 1/16″, 1/8″, 3/16″, and 1/4″ diameter. As a rule, a rod whose diameter equals the thickness of the metal should be used.

Preheating

Aluminum sheets 3/8″ or more in thickness, as well as the larger aluminum castings, should be preheated before welding to reduce the amount of oxygen and acetylene needed to melt the edges, and also to avoid heat strains. Castings, particularly, require careful heating to prevent any serious checks or cracks. Small castings may be preheated with the torch, while larger pieces should be placed in a furnace. Preheating is done at a temperature of 700° F. to 800° F. The temperature should never go beyond 800° F. because there is

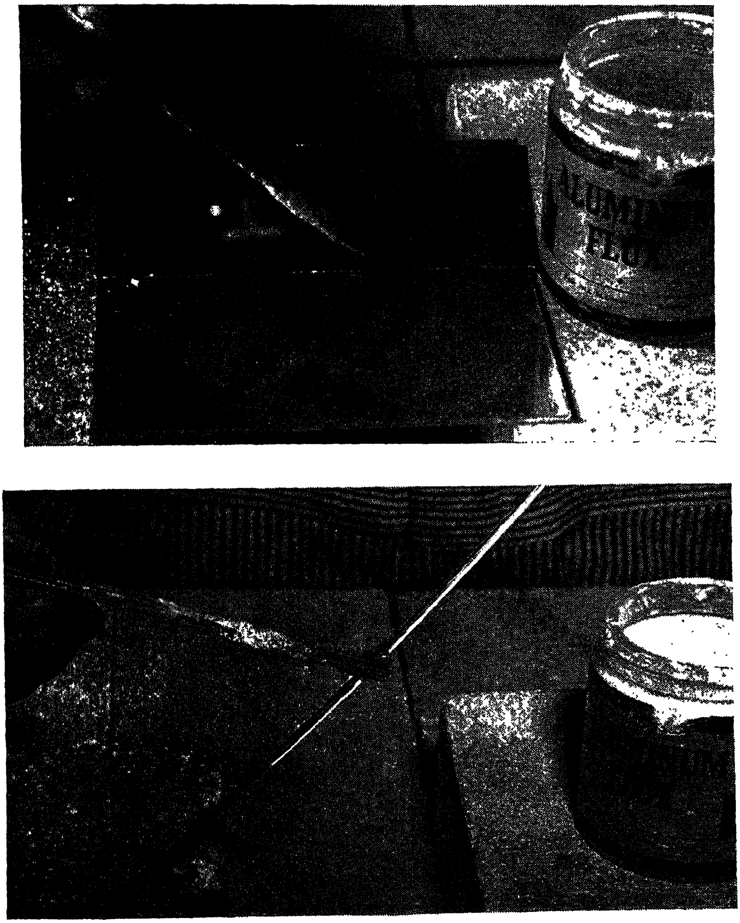

Fig. 79 a and b. Applying Flux

danger of burning out some of the valuable ingredients of the alloy.

If a pyrometer is not available, the correct preheating temperature may be determined by the following three methods:

1. If a pine stick is rubbed on the metal, a char mark will be left on it.
2. If a mark is made on the metal with a carpenter's blue chalk, it will turn white.
3. If the metal is struck with a hammer, no metallic ring will be heard.

Welding Tip

Since aluminum has such a high thermal conductivity, it is necessary to use a tip slightly larger than the one ordinarily used for steel of the same thickness. Table VIII shows the recommended sizes and gas pressure to use for welding aluminum of varying thicknesses.

TABLE VIII

APPROXIMATE SIZE OF TIPS AND RELATIVE GAS PRESSURES USED IN WELDING ALUMINUM OF DIFFERENT THICKNESSES

Oxy-Hydrogen				Oxy-Acetylene		
Metal Thickness B & S Gauge	Diam. of Orifice in Tip Inch	Oxygen Pressure Lb./sq. in.	Hydrogen Pressure Lb./sq. in.	Diam. of Orifice in Tip Inch	Oxygen Pressure Lb./sq. in.	Acetylene Pressure Lb./sq. in.
24–22	0.035	1	1	0.025	1	1
20–18	0.045	1	1	0.035	1	1
16–14	0.065	2	1	0.055	2	2
12–10	0.075	2	1	0.065	3	3
⅛–3⁄16	0.095	3	2	0.075	4	4
¼	0.105	4	2	0.085	5	5
5⁄16	0.115	4	2	0.085	5	5
⅜	0.125	5	3	0.095	6	6
⅝	0.150	8	6	0.105	7	7

COURTESY ALUMINUM COMPANY OF AMERICA

Flame

Many operators use hydrogen instead of acetylene for welding aluminum, and this in many cases is more desirable, especially for

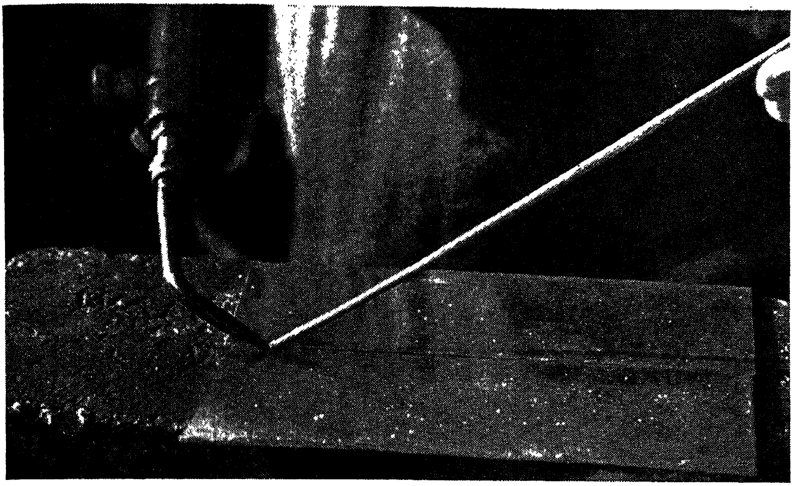

Fig. 80. Position for Welding Aluminum

welding light-gauge material. In either case, the torch should be adjusted so it will have a neutral flame. Some authorities recommend a slightly reducing flame but usually a neutral flame will be found to be the most satisfactory in producing a clean, sound weld. Whether using acetylene or hydrogen, the flame should be adjusted to a low gas velocity to permit a soft and not a "blowy" flame.

Torch Motion

The torch should be inclined at an angle of 30 degrees to the plane of weld. If held in a more vertical position, there is too much tendency for the flame to blow holes through the metal. The torch should be held with the inner cone approximately ⅛″ away from the metal.

Considerable care must be taken to heat both sides of the joint so that the heat will be distributed evenly. If a filler rod is used be sure that the base metal is beginning to melt before inserting the rod. Aluminum solidifies very quickly and, consequently, the molten metal cannot be made to flow as in the case of steel. Nevertheless, after a little practice, it is possible to secure good fusion, building the weld up to the desired height and producing a smooth, uniform ripple.

The rod should be held somewhat closer to the flame, as the heat of the molten pool is not as sufficient to melt the rod as in the case of steel. In fact, the tip of the rod needs to be held almost in the flame.

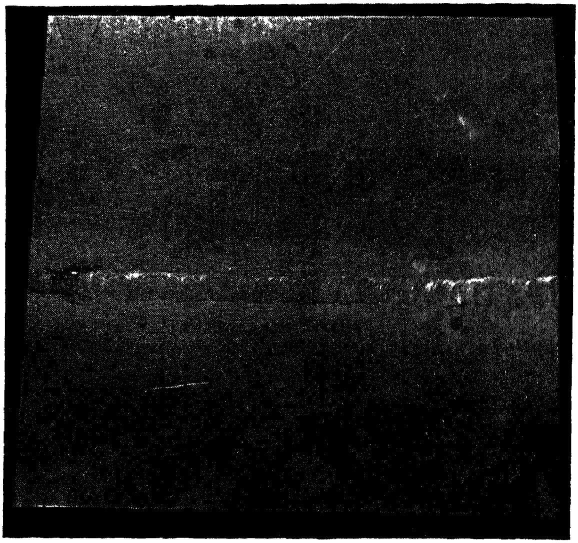

Fig. 81. Appearance of an Aluminum Weld

Welding Castings *

In general, the welding of aluminum-alloy castings requires technique similar to that used on aluminum-sheet and other wrought sections. However, the susceptibility of many castings to thermal strains and cracks, because of their intricate design and varying section thickness, should be carefully considered. In addition, many castings in highly stressed structures depend upon heat treatment for their strength, and welding tends to destroy the effect of such initial heat treatments. Unless satisfactory facilities for reheat treatment are available, the welding of such heat-treated castings is not recommended.

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* Reprinted from the booklet "Welding Aluminum" Courtesy of Aluminum Company of America.

When a broken aluminum casting is to be welded, it should first be cleaned carefully with a wire brush and gasoline to remove every trace of oil, grease, and dirt. Unless the casting has a very heavy cross section, it is not necessary to tool the crack or cut out a vee, as this can generally be accomplished by means of the torch and puddling iron. It is necessary, however, that the stock surrounding the defect be completely melted or cut away before proceeding with the weld. If a piece is broken out, it should be held in correct position by light, iron bars and appropriate clamps. The clamps should be so attached that the casting will not be stressed during heating.

If the casting is a large one or one with intricate sections, it should be preheated slowly and uniformly in a suitable furnace prior to welding. If the casting is small, or if the weld is near the edge and in a thin-walled section, the casting may be preheated in the region of the weld by means of a torch flame. Cast aluminum should be heated slowly, to avoid cracking in the section of the casting nearest the flame.

Broken pieces should be tack-welded into place as soon as the casting has been preheated. The actual welding of the piece should commence at the middle of the break, and welding should be done toward the ends. The welding rod must be melted by the torch, as the heat of the molten metal of the weld is not sufficient to melt it. When the weld is finished, the excess molten metal should be scraped off with a puddling iron, and the casting allowed to cool slowly.

Holes in castings are welded in much the same manner as are cracked and broken castings. It is necessary to melt away or cut away the sides of the hole in order to remove all pockets and to permit proper manipulation of the torch.

For welding ordinary castings an aluminum-silicon (Alcoa No. 43 alloy) or aluminum-copper-silicon (Alcoa No. 108 alloy) welding rod is generally used. However, in the case of heat-treated alloy castings, it is best to use a welding rod of the same alloy as the casting.

A flux should be used when welding aluminum castings. Puddling alone will merely break up the oxide film and leave it incorporated in the weld, while fluxing will cause the oxide particles to rise to the surface, resulting in a clean, sound weld. It is important that the added metal be completely melted and the molten metal thoroughly turned with the end of the welding rod or with a puddling iron. Thus the flux and oxide are worked to the surface of the molten metal, and there is very little danger of the finished weld becoming contaminated with particles of flux or other foreign material.

Aluminum Welding Exercises

Before attempting to do any welding, the beginner should take a small piece of aluminum, place it under the oxy-acetylene flame, and practice melting it. Note very carefully how the molten metal reacts. When sufficient time has been spent practicing this operation, proceed with the exercises listed.

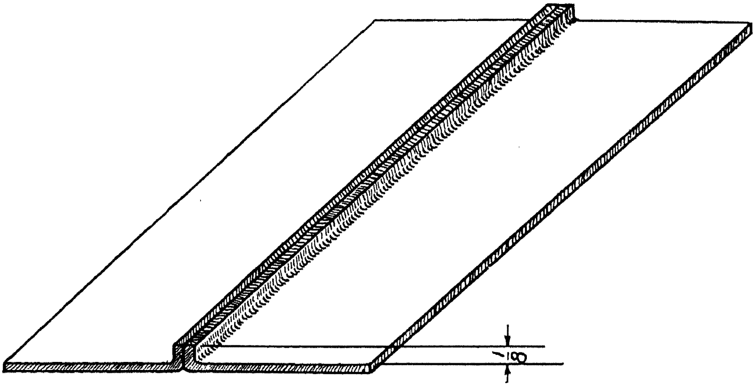

Fig. 82 Flange Joint

Practice Weld No. 1

The first practice weld consists of fusing the edges of a flange joint without the use of a rod. Secure two pieces of No. 18- or No. 20-gauge, 2S aluminum, 1½″ x 5″, and bend the edges at right angles as shown in Fig. 82.

Place the two pieces together and coat the seam with the prepared flux. Insert the correct size tip and with a soft neutral flame proceed to melt the two edges. It will be necessary to move the torch rapidly, since the metal is quite thin. Gradually keep raising the torch as the end of the joint is approached; otherwise, too much heat will have passed through the section, causing the metal to collapse suddenly.

Practice this exercise until a smooth, sound weld is obtained.

Practice Weld No. 2

The object of this job is to practice using the welding rod. Secure a strip of aluminum 1/16″ or 1/8″ in thickness. With the proper size rod, run a number of beads on the flat surface. Keep doing this until the knack of fusing the rod with the base metal has been mastered.

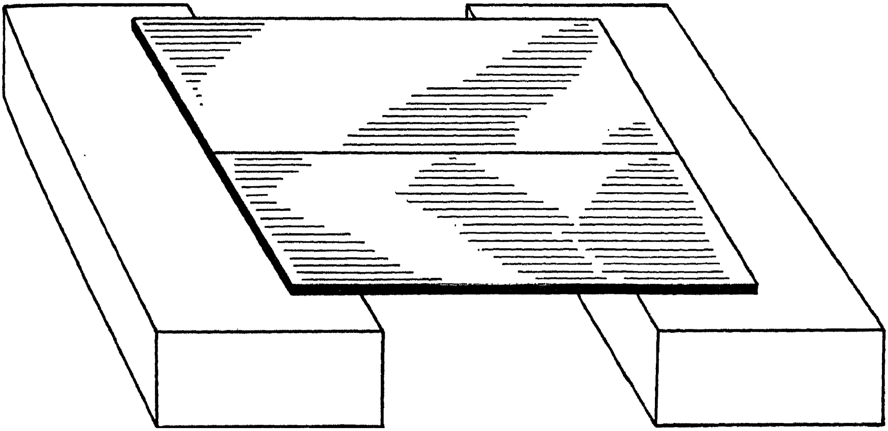

Fig. 83. Butt Joint for 1/16″ Aluminum

Practice Weld No. 3

The common butt joint is welded for this exercise, employing two strips of 1/16″ aluminum, 3″ x 5″. With the proper diameter rod, practice welding this joint until an even, smooth seam is obtained.

Practice Weld No. 4

Weld a butt joint, using 1/8″ aluminum, 3″ x 5″. The edges of this joint should be notched with the aid of a cold chisel. See Fig. 84.

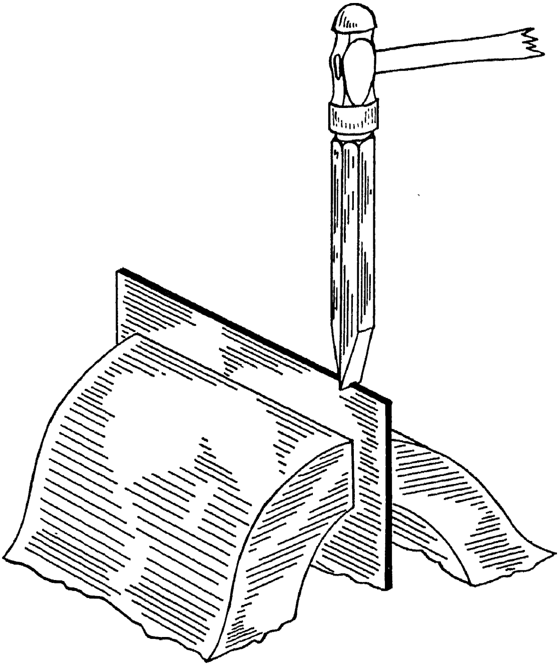

Fig. 84. Notching the Edges of Aluminum

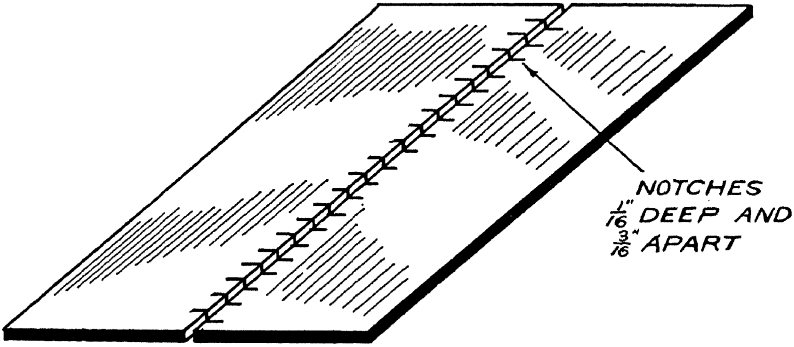

Fig. 85. Butt Joint on ⅛″ Aluminum

These notches act as expansion joints to prevent local distortion caused by the heat of the torch.

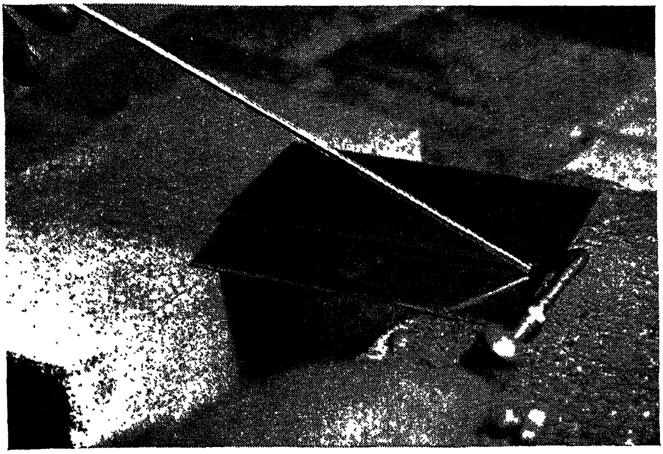

Fig. 86. Aluminum Lap Joint

Practice Weld No. 5

Weld a lap joint on two pieces of 1/16″ or 1/8″ aluminum, 3″ x 5″.

Practice Weld No. 6

Weld a corner joint on two pieces of light-gauge aluminum as shown in Fig. 87.

Practice Weld No. 7

Secure two strips of some light-gauge aluminum and with one of the pieces form a small cylinder. Butt-weld the seams of the cylinder and then weld this cylinder to a flat section. See Fig. 88.

Practice Weld No. 8

Plates ranging in thickness from 3/16″ and heavier, must be beveled to form a vee having an angle of approximately 90 degrees. The vee should extend to about 1/16″ or 1/8″ from the bottom of the plates.

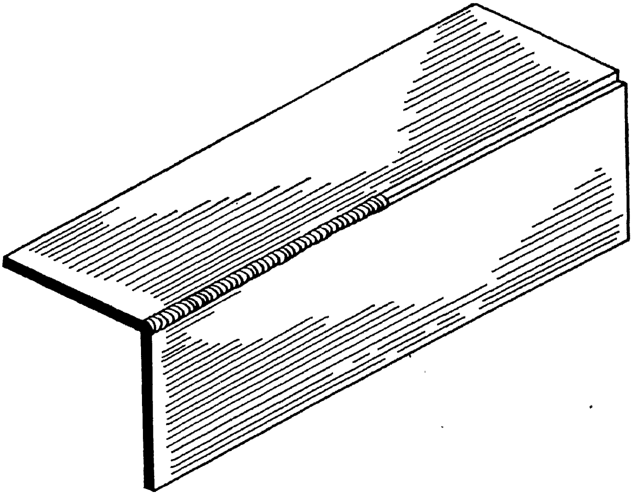

Fig. 87. Corner Joint

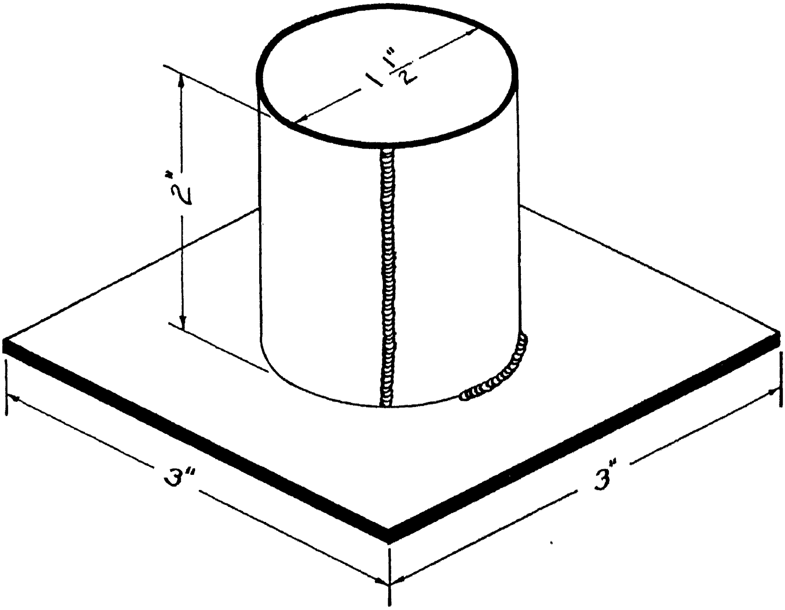

Fig. 88. Cylinder Weld

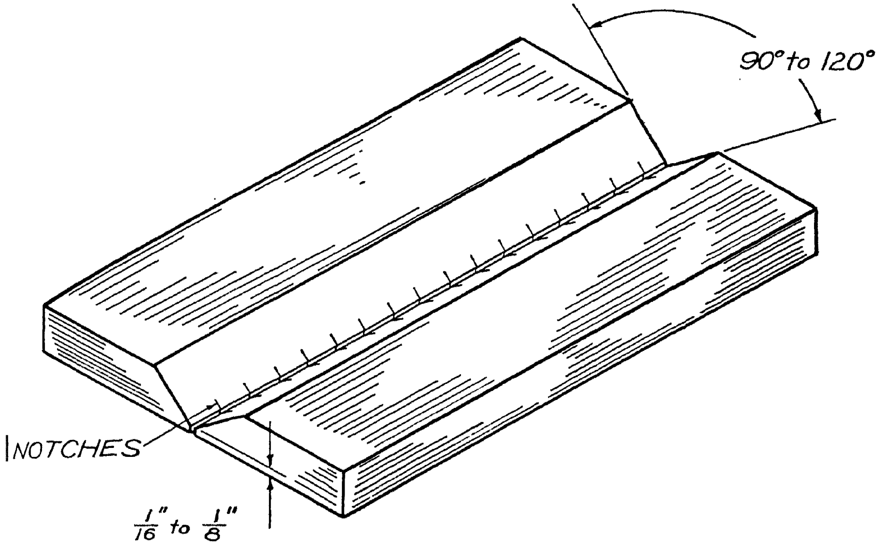

Fig. 89. Butt Joint of Single Vee for Aluminum .188″ and Up

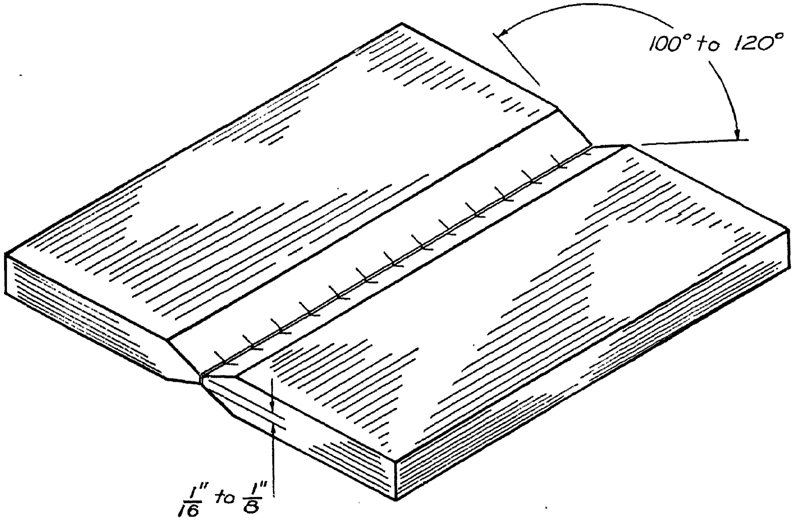

Fig. 90. Butt Joint of Double Vee for Aluminum .438″ and Up

Notches approximately 1/16″ deep and 3/16″ apart should be made with a cold chisel on the bottom of the vee. See Figs. 89 and 90.

Practice welding a number of aluminum pieces of varying thicknesses. If the plates are very heavy, necessitating deep vees, do not attempt to fill the groove in one pass. Resort to layer welding.

QUESTIONS

1. What are some of the outstanding properties of aluminum?

2. Into what groups may aluminum be divided?

3. What type of aluminum is the easiest to weld?

4. What ingredients are added to aluminum to strengthen it?

5. Name two types of heat-treated aluminum alloys that are most adaptable for welding.

6. What precaution must be taken when welding castings?

7. How can one determine when aluminum has reached its preheating temperature?

8. Why must flux be used to weld aluminum?

9. How is this flux applied?

10. What type of welding rod is recommended for welding 2S aluminum?

11. At what angle should the torch be inclined when welding aluminum? Why?

12. Why should the rod be held in the flame and not away from it as in welding steel?

13. Why are the edges of the pieces sometimes notched?

14. Why must castings be preheated before welding?

Unit 24

WELDING 18–8 CHROMIUM STEEL *

THE PROCEDURE used in welding 18–8 stainless steel is essentially the same as in welding ordinary steel. The only difference lies in the fact that certain special precautions must be more carefully followed. Greater care must be exercised in welding 18–8 steel, particularly of the treated or stabilized types, in order to obtain the most desired results.

Flame Adjustment Important

The properties of welds in stainless steels are greatly affected by the type of flame employed. The flame should be adjusted to give a neutral condition in which equal volumes of oxygen and acetylene are consumed. This regulation is understood and made without difficulty by those experienced in the use of the blowpipe.

Must Use Flux

The use of Cromaloy flux is strongly recommended in welding 18–8 steel. It makes the control of the molten metal easier, and also insures a sound, clean, good-appearing weld.

The application of flux to either the seam or the welding rod can be easily and quickly done by mixing the flux with water to the consistency of a thin paste and applying with a brush. The use of flux on the rod is particularly helpful in welding light-gauge sheet iron. Advantages are also gained by painting the underside of the seam with flux, since this prevents oxidation and allows a more perfect union to be made along the bottom of the seam.

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Welding Technique

Welding should be conducted in such a way as to prevent or minimize any tendency to puddle the weld. Puddling of the weld should be avoided because it increases the tendency toward oxidation and separation of valuable constituents. The preferable welding technique consists in holding the rod ahead of the blowpipe so that the molten metal melts in place or is melted simultaneously with the base metal to form a union between the parts being welded.

The heat used in welding stainless steel should be the minimum that will give the results desired. Excessive heat on molten, columbium-treated, 18–8 steel increases the loss of columbium during the welding. Normal heat keeps the loss of this element to a small, allowable percentage of that contained in the rod.

The choice between forehand and backhand welding depends chiefly on the skill of the operator in either method. In general, forehand welding is preferable on light-gauge sheet, while backhand welding is better on the heavier gauges.

When working on stainless steel, it is customary and advisable to weld from one side entirely. Care should be taken to fill the seam completely so that there will be no occasion to return to some point which should have been finished as the weld progressed.

It is important not to stop or to retrace a hot weld. If this must be done, wait until the weld cools entirely.

If it should become necessary to go back over a weld, or if there is need for welding at the back side of the seam in order to support points of severe stress, the entire seam should be preheated before the flame is applied to any local area of the joint. Such preheating is frequently undesirable because of the likelihood of warping the metal and because slow cooling is harmful to stainless steel. In other words, complete the weld in one pass, get thorough penetration in one pass, and do not make it necessary to work over or touch up a weld in any way.

Another operation against which the operator must be cautioned is welding away from an edge. In case it is necessary to weld away from an edge, begin the weld an inch or two in from the edge, then return to the starting point, later completing the weld to the edge.

The operator should familiarize himself thoroughly with the recommended procedure before any fabrication is attempted. The columbium-treated rod flows easily and smoothly, and very high quality welds may be expected. The welds will have good strength and will be completely corrosion resistant in the as-welded condition. The completed structure therefore may be used without the need of subsequent heat treatment.

Simplifying Fabrication Problems

It has been found helpful to place the parts being joined so that the line of weld inclines slightly downward in the direction of the welding. In this way, the flux, which fuses at lower temperatures than the steel, can flow forward and, consequently, provide protection for the metal as it fuses.

As compared to ordinary steel, the 18–8 stainless steels have a much higher coefficient of expansion, with, at the same time, lower thermal conductivity. Because of these properties, welding, especially when applied to thin material, may cause distortion and warping unless suitable provision is made to prevent this action. Clamps, copper chill plates, and jigs are used separately or in combination to hold the plates in line until the weld has cooled. Greater ease and speed in welding are other advantages obtained by the use of these appliances. Less absorption of heat in the part welded and more rapid chilling are also further advantages.

In most instances, sheets 1⁄16″ or less in thickness are flanged at the edge to a height of about 1⁄16″. The flanged edges are painted with the flux at both the top and bottom and are held in place as the flame melts down the flanges to form a smooth, moderately reinforced weld.

Slightly heavier sheets up to 1⁄8″ in thickness may have the edges butted together and oxwelded with some addition of metal from a welding rod. A backing strip, generally of copper, is used beneath the joint to prevent the liquid metal from flowing out of the weld.

For plates heavier than 1⁄8″, the edges should be scarfed to provide a vee so that fusion entirely to the bottom of the weld can be obtained easily. Welding rod is, of course, used in making the weld.

QUESTIONS

1. What type of flame is necessary to weld stainless steel?
2. Why is a flux required to weld stainless steel?
3. How may the flux be applied?
4. Why is a rapid weld desirable on stainless steel?
5. Why should the weld be completed in one pass?
6. Why should the pieces be inclined slightly downward in the direction of the welding?
7. How may warping be eliminated when welding stainless steel?
8. What is the function of a backing strip when welding sheets up to ⅛″ in thickness?

Unit 25

AIRPLANE WELDING

THE OXY-ACETYLENE welding process is extensively used in the fabrication of airplanes. The design of most aircraft demands an alloy steel tubing for some structural section in the fuselage, tail surfaces, or landing gear. At the present time the best method of joining this tubing is by oxy-acetylene welding.

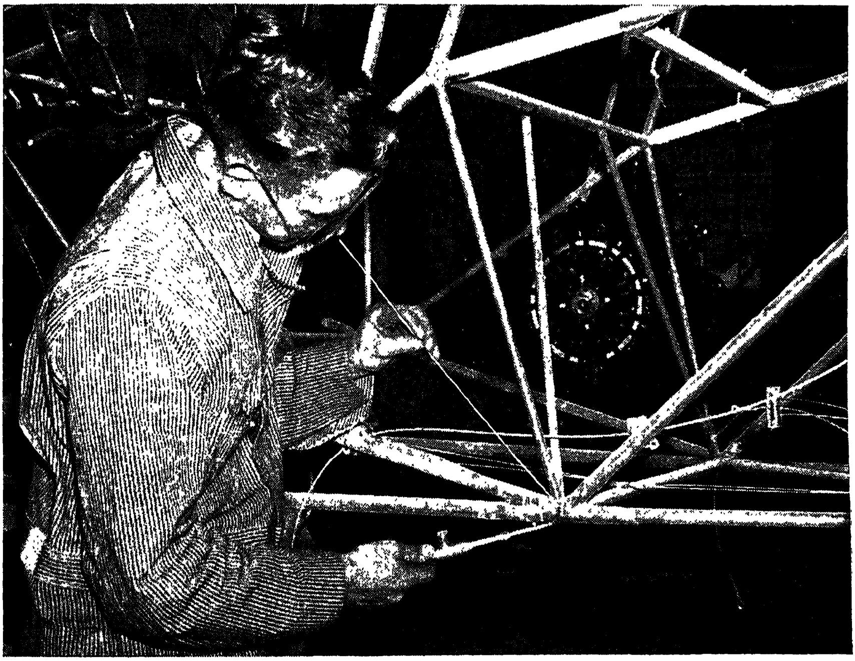

Fig. 91. Welding an Airplane Tubular Fuselage

Aircraft welding is a specialized field of its own, and although an individual may be an expert welder of other forms, this does not necessarily mean that he can satisfactorily weld airplane tubing. This type of welding involves more precision work, better technique in handling the torch in various positions and far greater responsibilities.

Preliminary Welding Practice

A great deal of airplane welding is done on very light tubing, and since this tubing is expensive a series of practice exercises should first be carried out using flat pieces of 20-gauge sheet metal.

The technique for welding light sheet metal is practically the same as that used for welding heavier plates. Many operators when welding this material prefer to use a continuous torch motion as shown in Fig. 92, instead of the regular, semicircular movement. This, of course, is optional and one should continue to use whatever motion is the most suitable for him to produce a satisfactory weld.

Fig. 92. Continuous Motion of the Torch

Preparation for Welding

Considerable attention must be given to the clearance between the joints to provide for proper expansion of the metal. A space ranging from 1/32″ to 1/16″ or more, depending on the thickness of the tubing, is required.

The pieces to be welded should be held in suitable jigs to keep them in perfect alignment and to prevent any distortion caused by the expansion and contraction forces generated during the welding operation.

Before any welding is begun, the pieces must be thoroughly cleaned by brushing the area to be joined with a wire brush or sandpaper.

Torch Size

A soft neutral flame should be used for welding aircraft tubing. The size tip is governed naturally by the thickness of the metal; care must be taken to provide a tip that will permit a rapid weld and at the same time will not produce such a hot flame that it will burn the metal. Burning the metal must be avoided, as it has a tendency to weaken the joint. This point is very important and must be kept constantly in mind when learning to weld tubing, because any slight defect in any section of an airplane is liable to cause a structural failure that may result in disaster.

TABLE IX

SIZES OF TIPS FOR VARYING THICKNESSES OF METALS

THICKNESS OF STEEL IN INCHES	DIAMETER OF HOLE	DRILL SIZE
.015 to .031	.026	71
.031 to .065	.031	68
.065 to .125	.037	63
.125 to .188	.042	58
.188 to .250	.055	54
.250 to .375	.067	51

Welding Rod

A low-carbon steel rod is used for welding chrome-molybdenum tubing. Although attempts have been made to use an alloy rod, experiments have shown that these rods do not offer enough advantages to offset the difficulty in using them. A low-carbon rod flows smoothly, making a clean, sound, uniform weld.

Condition of Completed Welds

Civil Aeronautics Manual No. 18 gives the following characteristics which a finished weld should incorporate:

1. The seam should be smooth and uniform in thickness.

2. The weld should be built up to provide extra thickness at the seam.

3. The weld metal should taper off smoothly into the base metal.

4. No oxide should be formed on the base metal at a distance of more than ½″ from the weld.

5. The weld should show no signs of blow holes, porosity, or ojecting globules.

6. The base metal should show no signs of pitting, burning, cracking, or distortion.

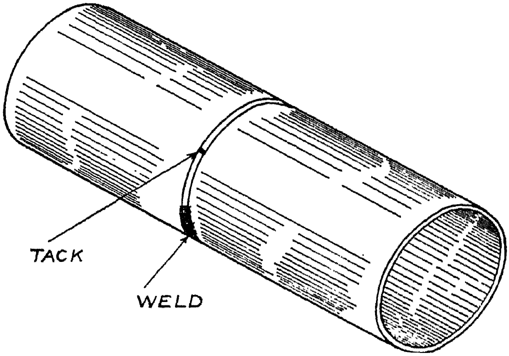

Fig. 93. Butt Weld

TUBULAR WELDING EXERCISE

Practice Weld No. 1: Butt Joint

Cut two pieces of tubing and tack-weld them in two places. Practice welding this joint first with the tubes in a horizontal and then in a vertical position. Frequently test the welded joint by cutting the tubing through the center, straightening it, and then bending it in the usual manner. See Fig. 94.

Practice Weld No. 2: Butt Weld on Flat Plate

Weld a short section of a piece of tubing on a flat plate. See Fig. 95.

Practice Weld No. 3: Tee Weld

Shape the vertical member to fit over the bottom piece. Tack the weld in place and weld around the joint without moving the tubing.

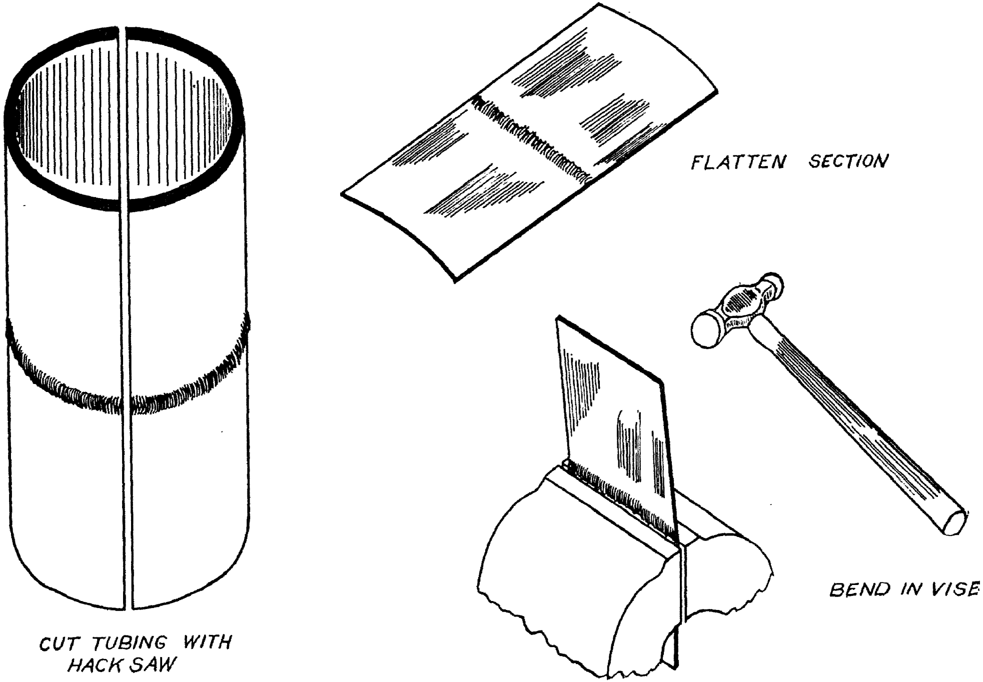

Fig. 94. Testing Tubular Butt Weld

Practice Weld No. 4: Angular Joint

Shape an angular piece to some desired angle, tack the two pieces together, and weld around the joint. See Fig. 97.

Practice Weld No. 5: Sleeve Joint

Insert one piece of tubing into another and weld. Avoid building up too high a fillet. See Fig. 99.

Practice Weld No. 6: Insert Plate Weld

The insert plate weld is made by simply cutting a slot in one end of the tubing and inserting a plate in the cut. A weld should be made along the four edges where the tube is in contact with the plate. See Fig. 100.

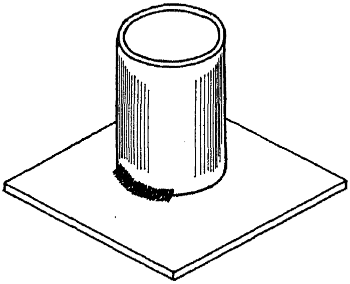

Fig. 95. Butt Weld on Flat Plate

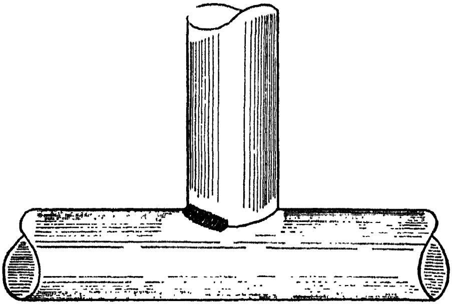

Fig. 96. Tee Weld

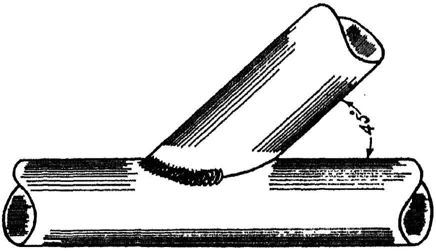

Fig. 97. Angular Weld

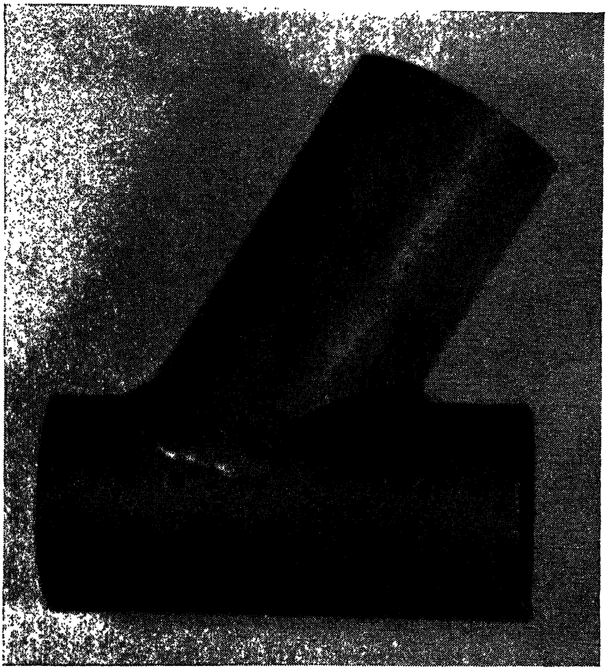

Fig. 98. Appearance of a Proper Tubular Weld

Practice Weld No. 7: Cluster Weld

Shape three pieces of tubing so that their centerlines will meet at one point. Tack them in place and weld around each tube. See Fig. 101.

REPAIR OF STEEL TUBE STRUCTURE

The repair of airplane tubular structure consists of removing damaged sections and replacing them with new pieces. The types of repairs that can be made are strictly governed by the Civil Aeronautics Board. The following splices are those that are shown in the Civil Aeronautics Manual No. 18, and their purpose here is to give the welder an opportunity to practice the correct technique in cutting, fitting, and welding them.

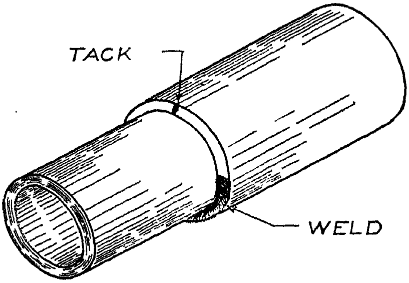

Fig. 99 Sleeve Weld

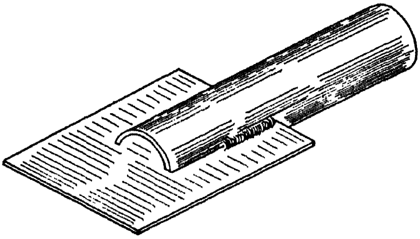

Fig. 100. Insert Plate Weld

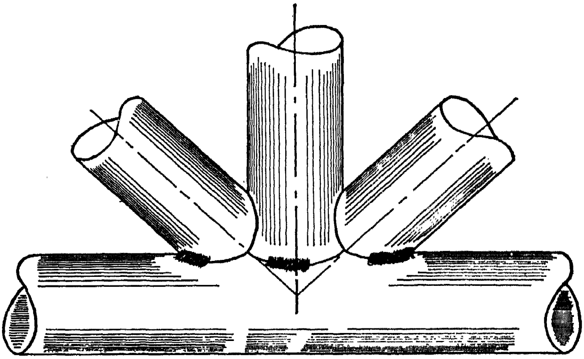

Fig. 101. Cluster Weld

Practice Weld No. 8: Repair of Members Damaged at a Station

Prepare a patch as shown in Fig. 102 and, after forming the fingers of the plate slightly, weld it to a cluster joint.

Practice Weld No. 9: Repair of a Dented or Cracked Tube in a Bay

Prepare two sleeves as shown in Fig. 103 and then weld to a tubular member.

Practice Weld No. 10: Repairs at Stations or Between Stations

Fuselage members may be repaired at a station or between stations by means of splices as shown in Fig. 104a, b, and c. Secure the

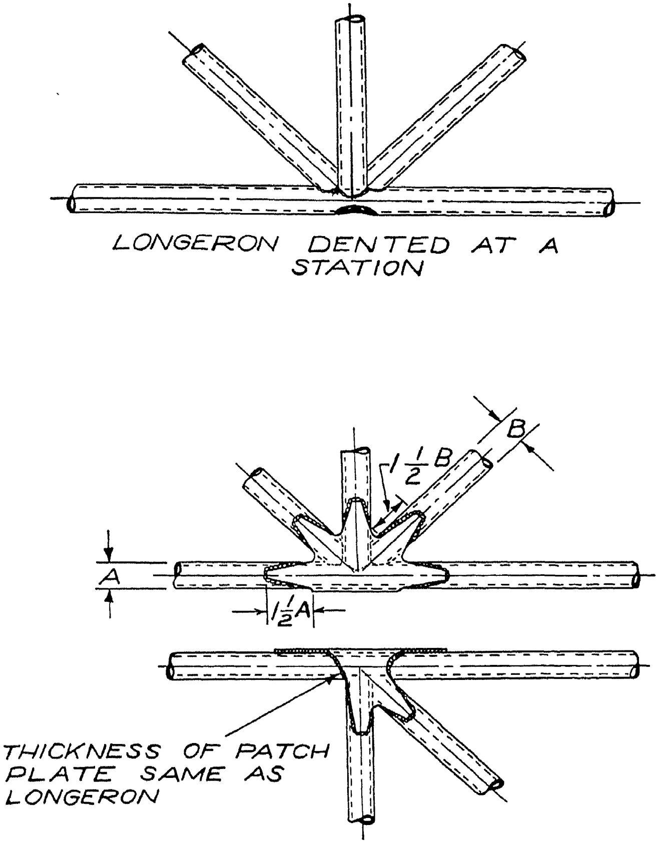
LONGERON DENTED AT A STATION
B
$1\frac{1}{2}B$
A
$1\frac{1}{2}A$
THICKNESS OF PATCH PLATE SAME AS LONGERON

Fig. 102. Patching a Plate in at a Cluster Joint

necessary pieces of tubing and practice making a number of these splices.

Practice Weld No. 11: Special Longeron Splices

A typical longeron splice using the same diameter replacement tube and which is considered the most efficient type of repair in this category is shown in Fig. 105. An equally satisfactory longeron repair, using a larger diameter replacement tube in connection with a fish-mouthed, telescoped joint, is shown in Fig. 106.

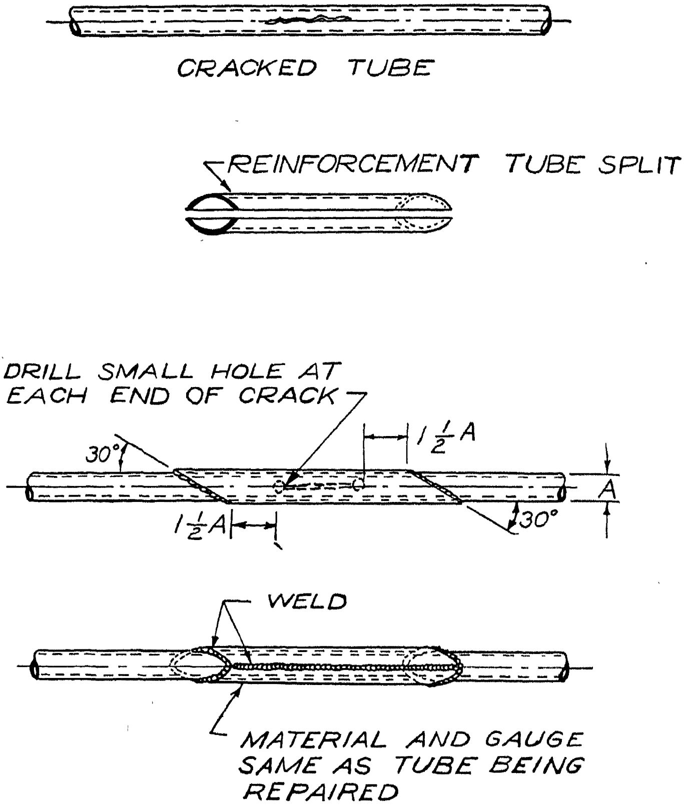
CRACKED TUBE
REINFORCEMENT TUBE SPLIT
DRILL SMALL HOLE AT EACH END OF CRACK
30°
$1\frac{1}{2}A$
A
$1\frac{1}{2}A$
30°
WELD
MATERIAL AND GAUGE SAME AS TUBE BEING REPAIRED

Fig. 103. Reinforcing Cracked Tube with Sleeve Patch

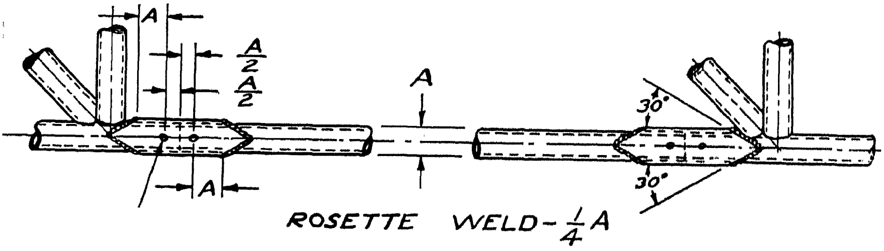

Fig. 104a. One Type of Splice

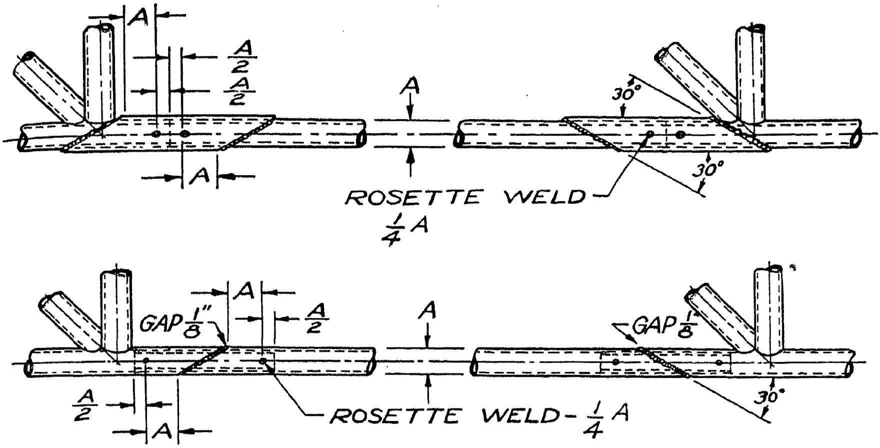

Fig. 104 b and c. Two Other Types of Splices

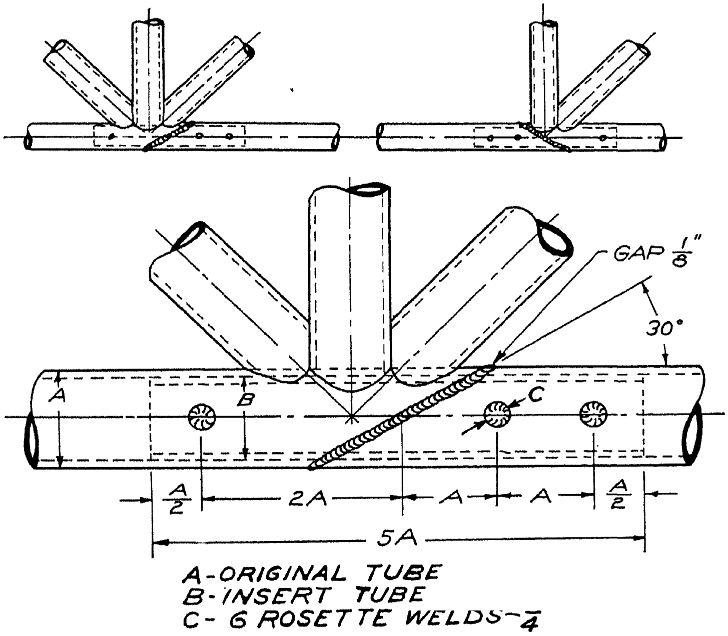

Fig. 105. Longeron Splice Using Equal-Diameter Replacement

Tubing Attachment

Whenever tubing is used for bracings, such as wing struts, landing gear sections, etc., the ends are provided with some fixture for attaching the members to their designated locations. Numerous fittings are also welded on various tubular pieces. The illustrations below picture a few of these common practices. The student should attempt to make a number of these welds in order to become familiar with the technique for welding them. No particular dimensions for the exercises are given, since their sizes are governed entirely by the type and size tubing required.

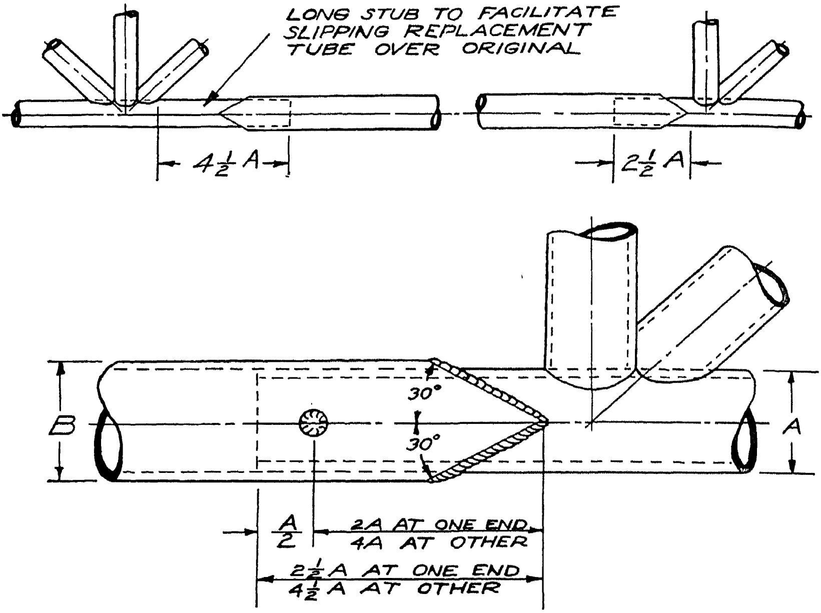

Fig. 106. Longeron Splice with Larger-Diameter Replacement

Practice Weld No. 12

Weld a sample of pieces shown in Figs. 107, 108, 109, 110, 111, and 112.

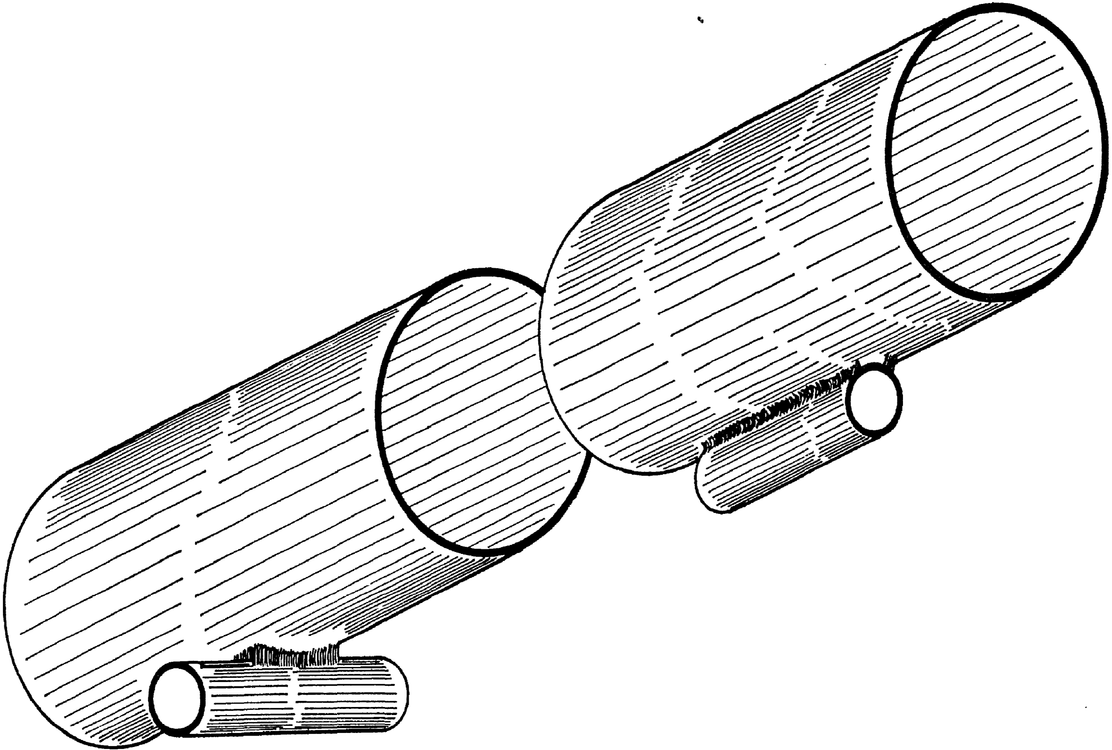

Fig. 107. Tubing Attachment Weld, #1

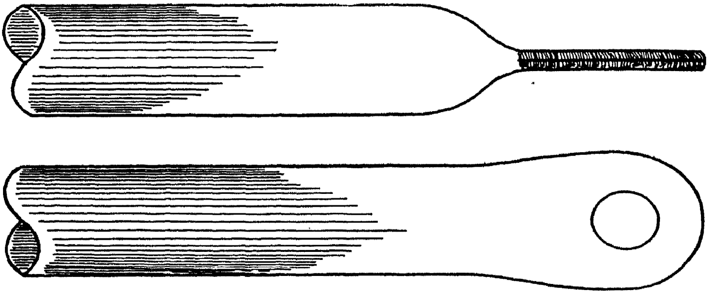

Fig. 108. Tubing Attachment Weld, #2

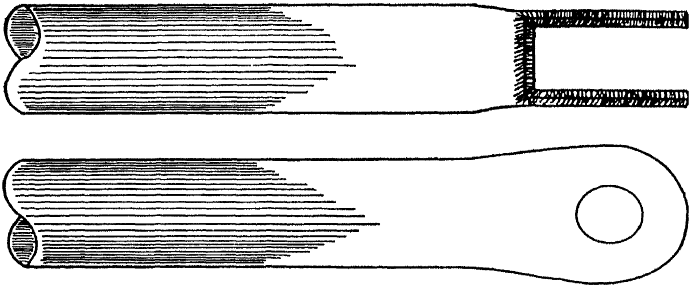

Fig. 109. Tubing Attachment Weld, #3

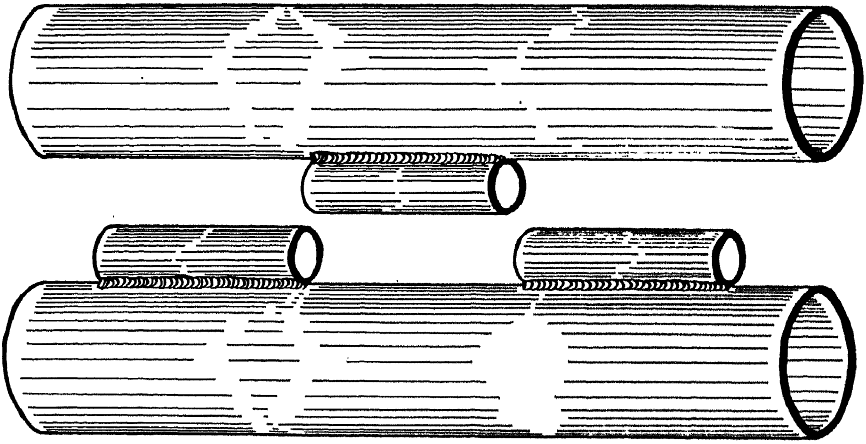

Fig. 110. Tubing Attachment Weld, #4

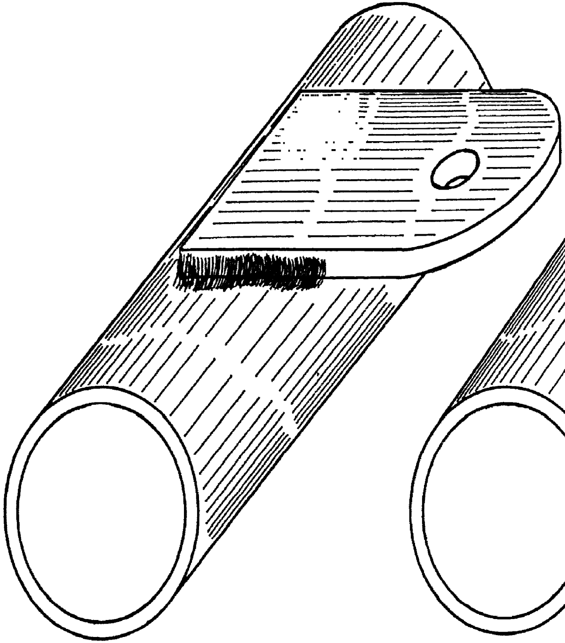

Fig. 111. Tubing Attachment Weld, #5

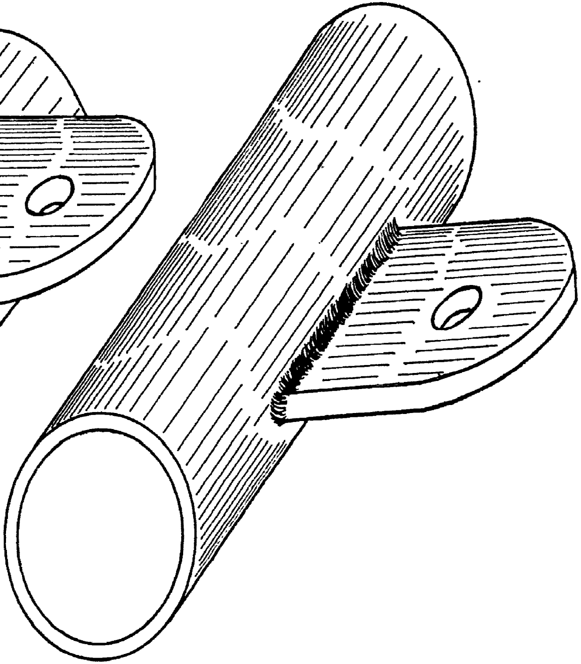

Fig. 112. Tubing Attachment Weld, #6

QUALIFICATION TEST FOR AIRCRAFT WELDERS

A student interested in airplane welding may be desirous of knowing what tests are required to qualify as an airplane welder. The following qualifications are those set up by the U. S. Air Corps, and these standards are usually demanded by industry when beginners apply as welders.

CLASS A WELDERS

Types of Metal: Plain carbon and alloy steels.

TEST

The test consists of welding the four following types of joints:

1. Open, single-vee butt weld
2. Tubular butt weld
3. Vertical fillet weld
4. Combination sheet-and-tube fillet weld

Joint 1. Open Single Vee Butt Weld *

This weld shall be made with a single reinforcement. The reinforcement shall be machined off and the sample cut up into test specimens of the form and dimensions shown in Fig. 113. Not less than three specimens shall be cut from the sample. A tensile test shall be made on each specimen, and the average strength for the three samples shall not be less than given in Table X. The strength of any individual specimen shall not be less than 90 per cent of the average value given in this table.

TABLE X

TENSILE STRENGTH WELD METAL—POUNDS PER SQUARE INCH

CARBON CONTENT OF FILLER ROD	CARBON STEEL BASE METAL	ALLOY STEEL BASE METAL
Up to 0.06 incl.	45,000	55,000
0.07 to 0.12	50,000	65,000
Over 0.12	55,000	70,000 [1]

[1] These values shall be used for alloy steel filler rod.

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* Courtesy U. S. Army Corps.

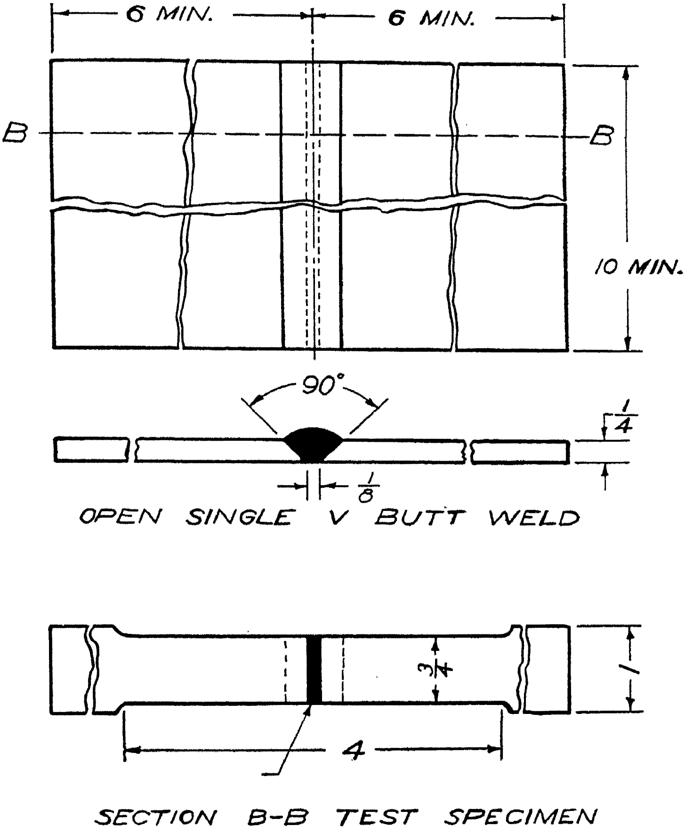


Fig. 113. Open Single V Butt Test Weld

Joint 2. Tubular Butt Weld

This is an open butt weld and shall be made with the tubes in a horizontal position for one specimen and in a vertical position for a second specimen. One set consisting of a horizontal and a vertical specimen shall be welded on the bench and a similar set in an overhead position not lower than the welder's eyes. The overhead specimens shall not be rotated. The joints shall be tested as tensile specimens, with the reinforcement. The strength of the joint shall not be less than 50,000 pounds per square inch for plain carbon steel and 80,000 pounds per square inch for alloy steel, calculated on the area of the base metal.

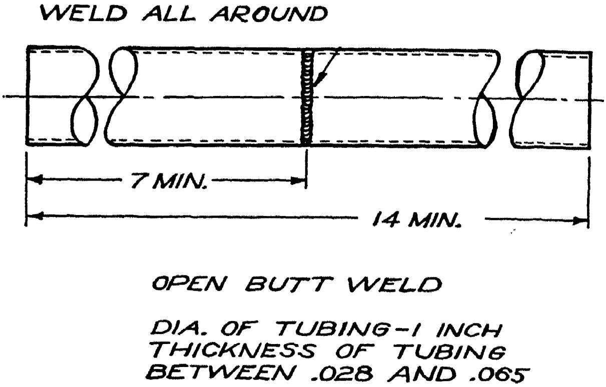


Fig. 114. Tubular Butt Test Weld

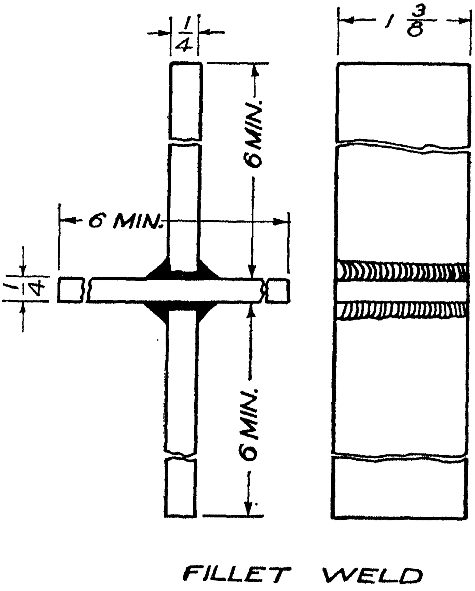
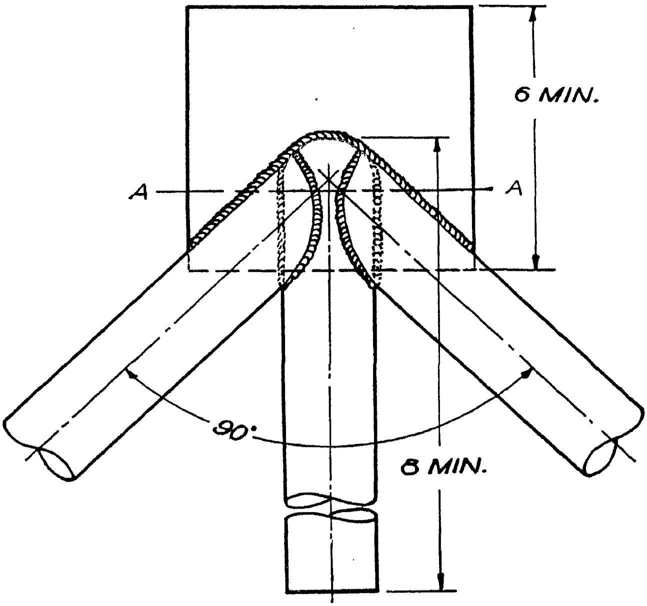


Fig. 115. Vertical Fillet Test Weld

Joint 3. Vertical Fillet Weld

This joint shall be made with the sheet standing on edge. The pieces shall be supported so that there is a clearance between the lower end of the seam and the jig. The joint shall be tested in tension. The joint shall develop not less than 10,000 pounds per linear inch if the base metal is plain carbon steel and 15,000 pounds per linear inch for alloy steel. The broken specimen shall be examined to determine whether or not the weld has been fused into the base metal in the corner.



THREE TUBE JOINT
DIA. OF TUBING—1 INCH
THICKNESS OF TUBING
.065 INCH
THICKNESS OF SHEET
$\frac{1}{4}$ INCH

Fig. 116. Combination Sheet and Tube Fillet Test Weld

Joint 4. Combination Sheet and Tube Fillet Weld

This joint shall be cut at Section AA, and either half shall be polished and etched with 50 per cent aqueous hydrochloric acid at a temperature of approximately 180° F. (82° C.) for a sufficient length of time to bring out the boundaries between the welded metal and the base metal. A visual examination of the section shall be made in order to determine the presence of blowholes or porosity in the weld metal, and the penetration of the weld metal into the base metal. A penetration between 25 and 40 per cent below the surface of the base metal is desired in the case of material ⅛″ or thicker. The penetration may be greater than this for thinner materials.

QUESTIONS

1. Why are greater responsibilities required of aircraft welders?

2. What are the most common types of tubing used for aircraft construction?

3. What type of rod and flame should be used for welding aircraft tubing?

4. Why should extreme precautions be taken not to burn the metal when welding airplane tubing?

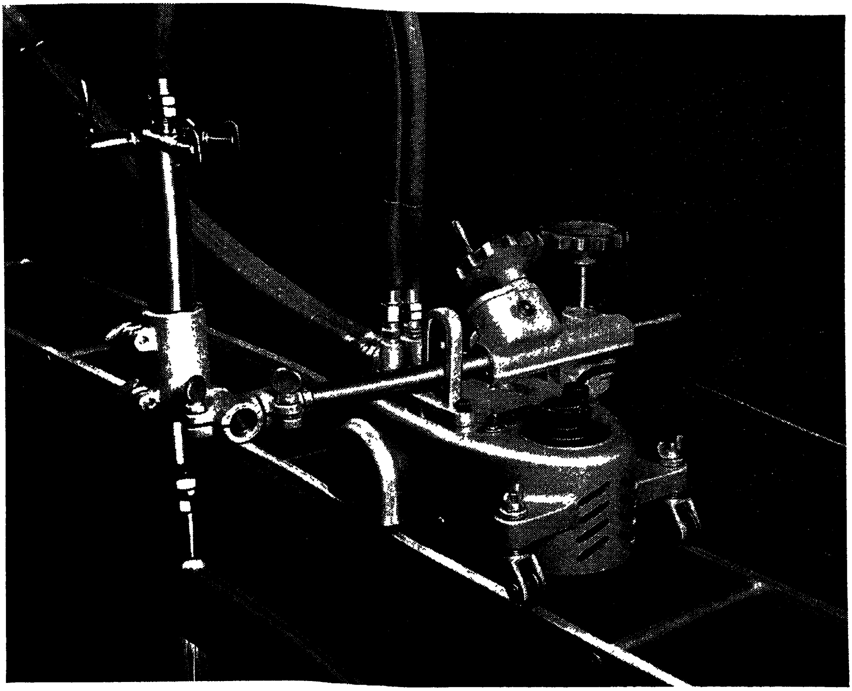
5. Why is it important that the tubular pieces be properly spaced?

6. If a weld shows indications of blowholes or globules, why is it considered a poor weld?

Unit 26

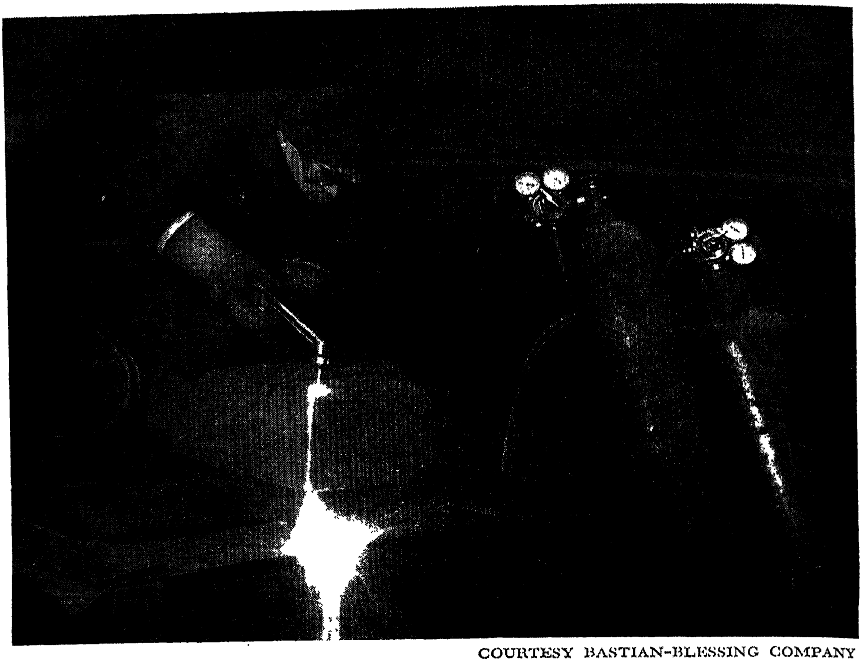
FLAME CUTTING

THE CUTTING OF METAL by the oxy-acetylene process is widely used in many industrial fields. The cutting may be done by means of a simple, hand cutting torch or by a more complicated, automatically controlled cutting machine. See Fig. 117.



COURTESY BASTIAN-BLESSING COMPANY

Fig. 117. Automatic Flame-cutting Machine



COURTESY BASTIAN-BLESSING COMPANY

Fig. 118. Cutting Heavy Steel with a Cutting Torch

The severing of metal by this process is made possible by the fact that ferrous metals are subject to oxidation. When a piece of wrought iron or steel is left exposed to various atmospheric conditions, a reaction known as rusting begins to take place. This rusting is simply the result of the oxygen in the air uniting with the metal, causing it gradually to decompose and wear away. Naturally this action is very slow but, if the metal is heated and permitted to cool, heavy scales form on the surfaces, showing that the iron oxidizes much faster when subjected to heat. Now, if a piece of steel were to be heated red hot and dropped in a vessel containing oxygen, a burning action would immediately take place, reducing the metal to an iron oxide commonly known as slag.

In order to make possible the rapid cutting of metal, it is necessary to have an implement that will heat the iron or steel to a certain temperature and then throw a blast of oxygen on the heated section. The cutting torch, whether operated manually or by machine, functions in just such a manner. See Fig. 118.

The Cutting Torch

The cutting torch varies somewhat from the regular welding blowpipe in that it has an additional lever for the control of the oxygen used to burn the metal. It is possible to convert the welding torch into a cutting torch simply by replacing the mixing head with a cutting attachment.

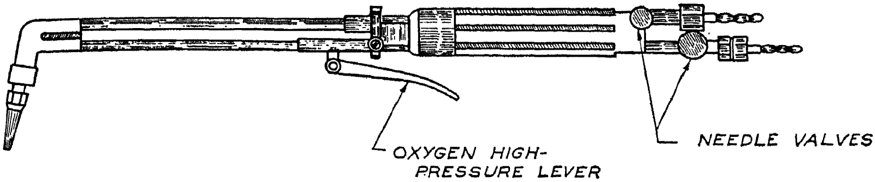


Fig. 119. Flame-cutting torch

It will be noticed from Fig. 119 that the torch has the conventional oxygen and acetylene needle valves. These are used to control the passage of oxygen and acetylene when heating the metal. Many cutting torches have two oxygen needle valves for securing a finer adjustment of the neutral flame. The cutting tip is made with an orifice in the center surrounded by several smaller ones. The

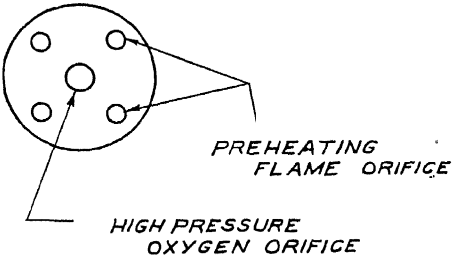


Fig. 120. Cutting Tip

center opening permits the flow of the cutting oxygen and the smaller holes are for the heating flame. Usually four different tip sizes are provided for cutting metals of varying thicknesses. In addition, special tips are made for other purposes, such as for cleaning metal, cutting rusty, scaly or painted surfaces, rivet washing, etc.

Pressure

The pressure of oxygen and acetylene needed will depend upon ıe size tip used, which in turn is governed by the thickness of the metal to be cut. Table XI illustrates the approximate pressure for various tip sizes for a particular type of cutting torch.

TABLE XI

CUTTING PRESSURE

TIP No.	THICKNESS OF METAL, *Inches*	ACETYLENE PRESS., LBS.	OXYGEN PRESS., LBS
1	⅛	4	10
1	¼	4	15
1	⅜	4	20
1	½	4	25
2	¾	5	30
2	1	5	40
2	1½	5	50
2	2	5	60
3	3	6	70
3	4	6	80
3	5	6	90
4	6	7	100
4	8	7	130
4	10	8	150

COURTESY MODERN ENGINEERING CO.

It is always well to consult the manufacturer's recommendations for your particular torch as to the proper oxygen and acetylene pressure. The given oxygen pressure cannot always be strictly followed because, for example, steels may have an exceptionally heavy coating of rust or scale and, if so, will require a somewhat greater oxygen pressure to make the oxygen burn entirely through the metal.

Lighting the Torch

Turn on the acetylene needle valve and light the gas as if for welding. Be sure while the acetylene is burning that there is a slight gap of 1/32″ to ⅛″ between the burning gas and the tip. Now turn on the oxygen valve and adjust it for a neutral flame. This flame is the one used to bring the metal to a kindling temperature, which, for example, in the case of plain carbon steel, is 1400° F. to 1600° F. Observe the nature of the cutting flame by pressing down the oxygen control lever. When the oxygen pressure lever is turned on it may be necessary to make an additional adjustment to keep the preheating cones burning with a neutral flame.

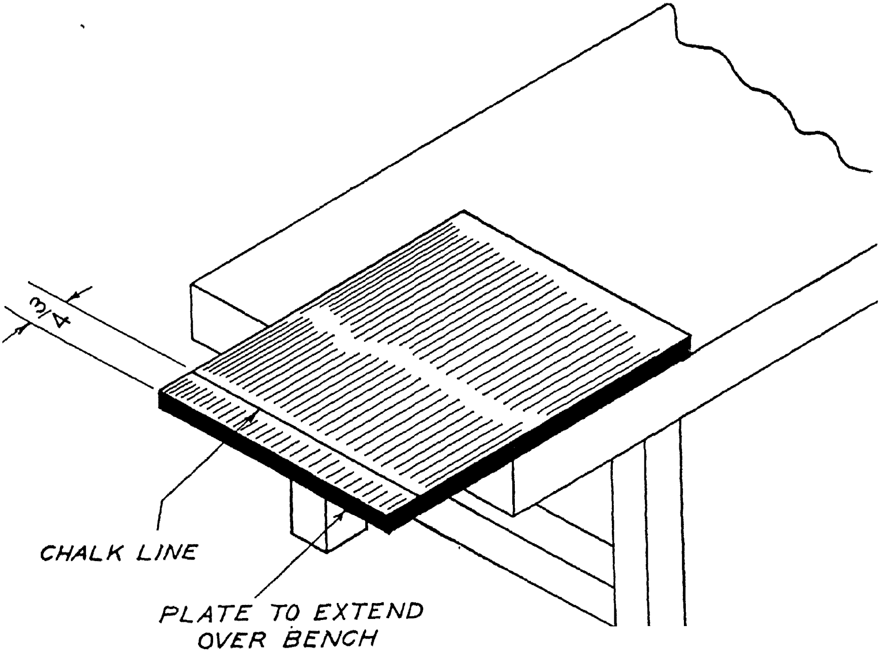


Fig. 121. Preparing Steel Plate for Cutting

Cutting Steel

It is well for the beginner to practice making straight cuts. To aid in keeping the cut in a horizontal line, rule a chalk line about ¾″ from one edge of the plate. Place the plate so this line clears the edge of the welding bench. See Fig. 121.

With the torch adjusted to a neutral flame, grasp the blowpipe handle with the right hand in such a position as to permit instant access to the oxygen control lever. This valve is usually operated either with the thumb or forefinger.

The knack of making a clean, straight cut depends on how steady the torch is held. Naturally, when the tip wavers from side to side, a wide kerf will result, which means a rough cut, slower speed, and greater oxygen consumption. To help keep the blowpipe steady it is well to hold the elbow or forearm on some convenient support. Holding the torch with the left hand will also permit guiding the nozzle in the direction desired.

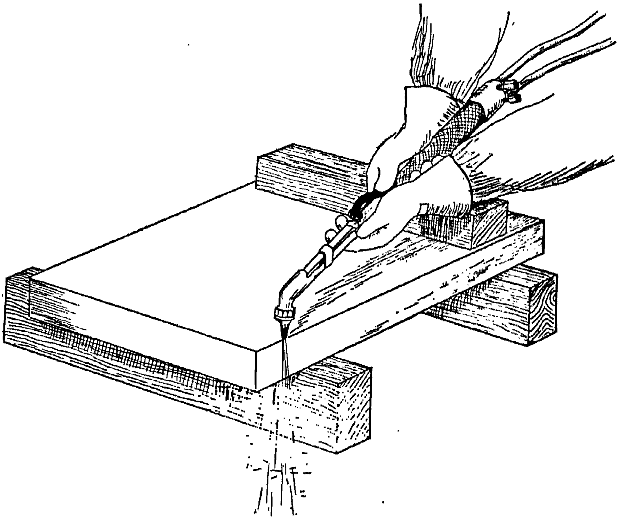


Fig. 122. Starting the Cut

As a rule, the cut is started at the edge of the plate. The torch is held with the tip in a vertical position to the surface of the metal, with the inner cone of the heating flame approximately 1/16″ above the chalk line. Keep the torch in this position until a spot in the metal has been heated to a bright red heat. Now gradually press down the oxygen pressure lever and move the torch forward slowly along the chalk line. The movement of the torch should be just rapid enough to insure a fast but continuous cut. A shower of sparks will be seen to fall from the underside, indicating that the penetration is complete and the cut is proceeding correctly. If the cut does not seem to go through the metal, close the oxygen pressure lever and reheat the metal until it is a bright red again. If the edges of the cut appear to melt and have a very ragged appearance, the metal is not burning through and the torch is being moved too slowly.

When an exceptionally straight cut is desired it is a good idea to clamp a bar of steel across the plate to act as a guide for the torch to follow.

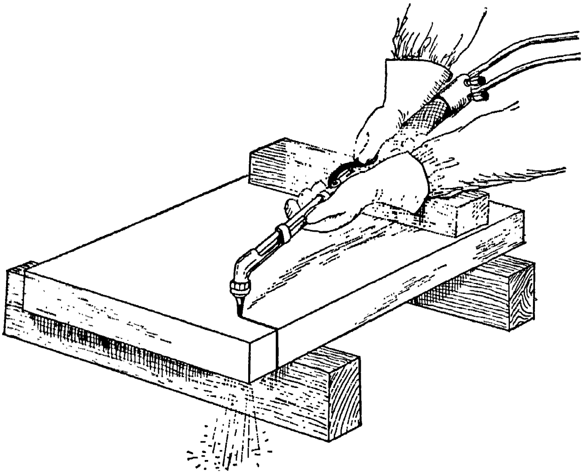


Fig. 123. Cut Proceeding the Right Way

The beginner will probably experience having the pieces stick together even when the cut has penetrated through. This is due to the slag, produced by the cutting, flowing across the metal pieces. However, this is no serious fault, as the slag is quite brittle and a slight blow with a hammer will separate the two sections.

It may be necessary sometimes to start the cut in from the edge of the plate. In such a case, hold the preheating flame a little longer on the metal, then raise the cutting nozzle about ½″ and pull the oxygen lever. When a hole is cut through, lower the torch to its normal position and proceed with the cut in the usual manner.

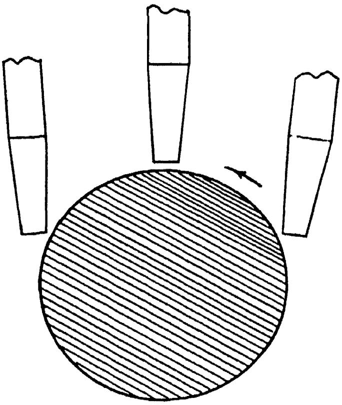


Fig. 124. Cutting Round-Bar Stock

Cutting Round-Bar Steel

To sever round stock the cut is started about 90° from the top edge, as shown in Fig. 124. The torch must be kept in a perpendicular position and gradually lifted to follow the circular outline of the bar. This position of the blowpipe is kept while ascending as well as descending on the opposite side.

Beveling

To make a bevel cut on a steel plate, it is necessary to incline the head of the torch to the desired angle instead of holding it vertically. An even bevel may be made by resting the edge of the nozzle on the work as a support or be guided by means of a piece of angle iron clamped across the plate. See Fig. 125.

Piercing Holes

It may be necessary at times to make a series of holes through a plate of steel. This can easily be done by means of the cutting torch. Hold the torch over the spot where the hole is to be cut until the flame has heated a small, round spot. Gradually pull the oxygen lever and at the same time raise the nozzle slightly. In this manner a small, round hole can be pierced quickly through the metal.

If larger holes are required, first trace the shape of the openings with a piece of chalk. At some point inside the outline, pierce a small hole as described and then start the cut from this point, gradually working to the chalk line and continuing around the outline.

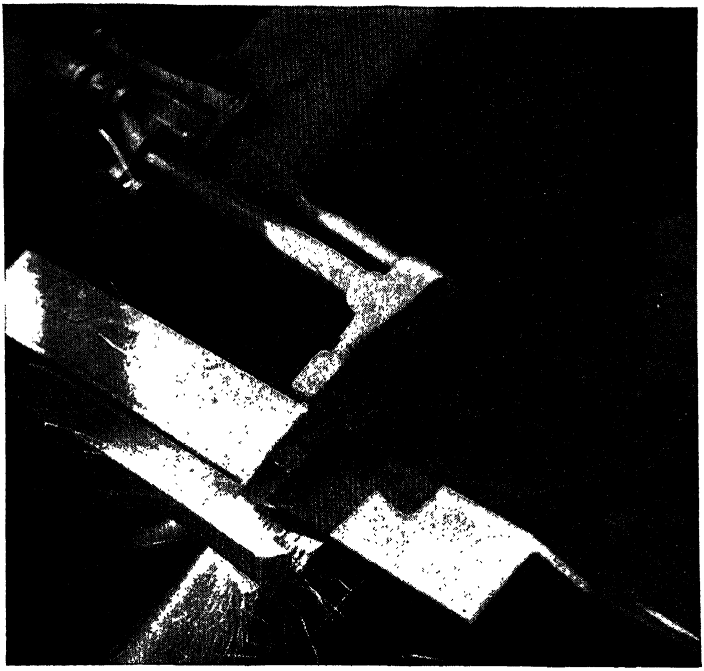


Fig. 125. Beveling with a Cutting Torch

Cutting Cast Iron *

To intelligently describe this process, we must first consider the nature of cast iron from two angles. Since it has such a wide range of use, it is natural that we may expect a wide difference in quality or chemical composition and a corresponding difference in ease of cutting. The better grades of castings, such as machined, are more easily cut, and those of random grades of scrap, such as counterweights, gratebars, floorplates, etc., present greater difficulty, requiring more gas, a wider kerf, and a corresponding slower rate of cutting speed. Different thickness is also a factor which will be considered later, under the heading Cutting Procedure.

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* Reprinted by the courtesy of Modern Engineering Co.

Preparation

There is a rule for heavy steel cutting which certainly applies in every way to cast-iron cutting, and that is, DO NOT START THE CUT UNTIL YOU ARE CERTAIN THAT YOU CAN COMPLETE IT. It is obvious that, if the cut is stopped on a heavy section, it is extremely difficult to start it again, and may doubly increase the cost as well as the annoyance. Considerably more heat, as well as sparks and slag, is generated in cast iron, so that proper protection to the body, face, and limbs is necessary. Asbestos gloves are essential, and a fire brick or suitable torch rest is desirable.

TABLE XII

PRESSURE TABLE FOR CUTTING CAST IRON

SIZE OF TIP	THICKNESS OF METAL	OXYGEN PRESSURE	ACETYLENE PRESSURE
L-3CH	½″	40 lbs.	7 to 8 lbs.
	¾″	45 lbs.	
	1″	50 lbs.	
	1½″	60 lbs.	
	2″	70 lbs.	
L-4CH	3″	80 lbs.	8 to 10 lbs.
	4″	90 lbs.	
	6″	110 lbs.	
	8″	120 lbs.	
	10″	150 lbs.	
	12″	170 lbs.	

Cutting Procedure

For cutting the better grades of cast iron or gray iron, set the regulator to deliver the proper pressure as indicated on the pressure table. The regulator adjustment, of course, is made with the high-pressure cutting valve open to compensate for the customary drop in pressure when the gas is released.

Next, light the torch and adjust the preheating flame so that it will show an excess of acetylene. This is done preferably with the high-pressure valve wide open to avoid any change in the character of the flame during the actual cutting operation. This is important! The excess acetylene, as indicated by the length of the white cone, must be varied to best suit the grade and thickness of the material cut. Experience is naturally the best guide on this point. However, it will generally vary from little or no excess of acetylene for the extremely light sections to an excess indicated by a white cone of a length of one to two inches for the heavier sections cut.

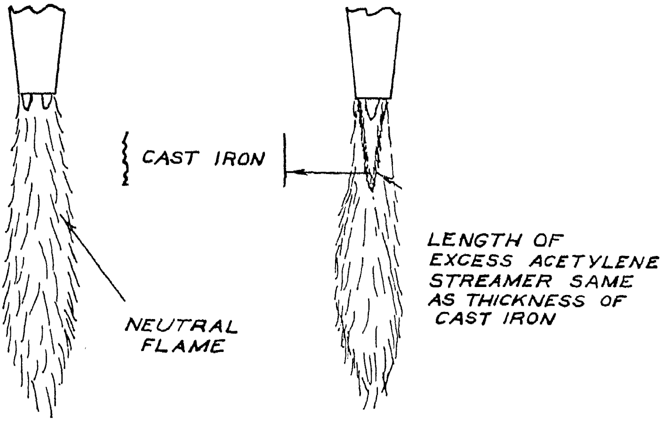
CAST IRON
NEUTRAL FLAME
LENGTH OF EXCESS ACETYLENE STREAMER SAME AS THICKNESS OF CAST IRON

Fig. 126. Cast-Iron-cutting Flame

Due to the higher cost of cast-iron cutting, it is well to plan the work carefully: first, to avoid any unnecessary cuts, and then to take advantage of all helpful hints. As the cutting of cast iron requires a higher ignition temperature, some gas can be saved by preheating the heavier sections along the line of the start of the cut.

Bring the tip of the torch to the top or starting point, as indicated in Fig. 128. Hold the torch on an angle of approximately 40 to 50 degrees and heat a spot about ½″ in diameter to a molten condition.

With the end of the shorter, preheating cone about 3⁄16″ from the metal, start to move the torch with a swinging motion shown in Fig. 127 and open the high-pressure cutting valve. Gradually bring the torch along the line of the cut, continuing the swinging motion. As the cut progresses, gradually straighten the torch to an angle of 65 to 70 degrees, as shown in Fig. 129, which will help to facilitate the penetration.

If the first attempt is a failure, keep trying, as the additional heat is favorable to cast-iron cutting. Success will follow. The width of the cut will vary with the thickness and grade of cast iron, being wider for the heavier sections or poorer grades. Practice alone governs this. However the same old rule of steel cutting applies, and that is that the cut must penetrate entirely through the section. In fact, it is quite necessary, due to the greater amount of slag and sparks which develop.

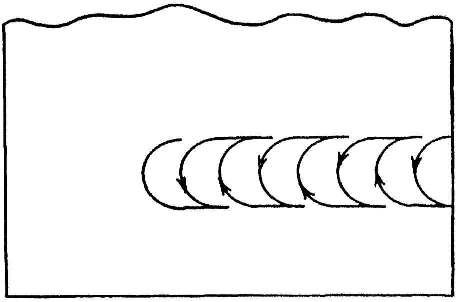

Fig. 127. Movement of Cutting Torch

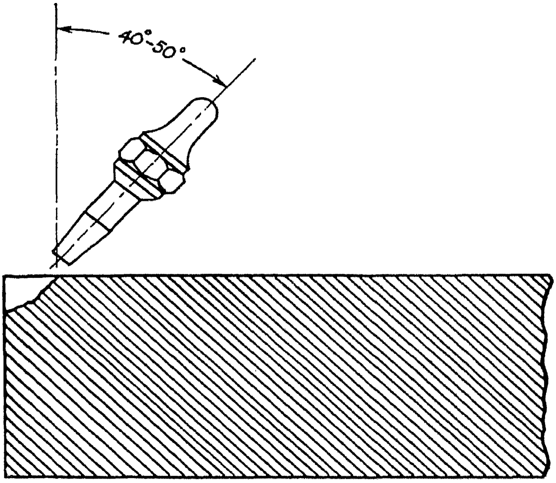

Fig. 128. Position of Torch to Start Cutting Cast Iron

The same swinging movement is continued throughout the entire length of the cut. As the operator gains experience and confidence, he will be able to reduce somewhat the length of the arc of this swinging motion, thereby reducing the width of the kerf and corresponding amount of gas consumed.

On the heavier sections, sufficient heat is usually developed to allow the cut to proceed without interruption. On the lighter sections, however, more difficulty is experienced. The operator is frequently bothered with losing his cut; in other words, the surface of the metal cools too rapidly and only a slight groove is made in it by the flame. Start over again by heating a small circle as previously described, but gradually raise the torch and incline it so as to cut away the lower portion of the section. Then proceed as before. As long as the exposed side of the cutting groove appears bright, continue the cut until it is completed.

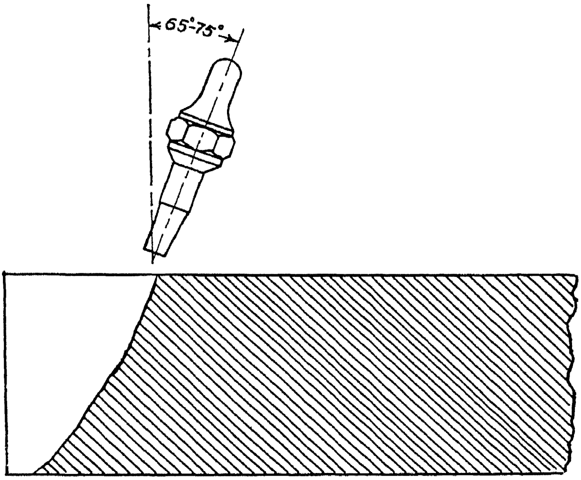

Fig. 129. Advanced Position in Cutting Cast Iron

CUTTING EXERCISES

Practice Cut No. 1

Secure a piece of ¼″, ⅜″, or ½″ steel plate and rule off chalk lines

¾″ apart. Fit the proper size cutting tip and proceed to cut these strips. See Fig. 130.

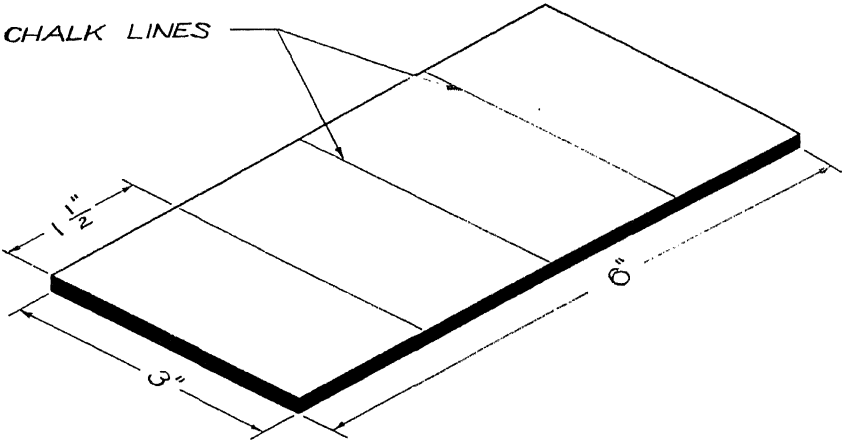

Fig. 130. Practice Cut No. 1—Cutting Strips

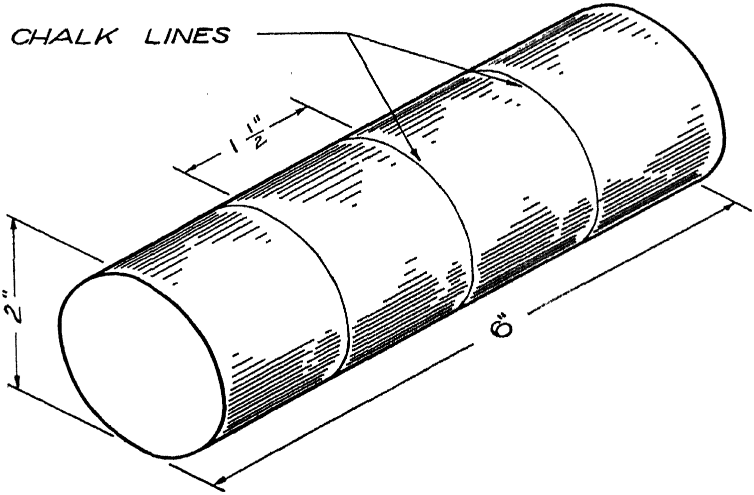

Fig. 131. Practice Cut No. 2—Cutting Round Stock

Practice Cut No. 2

Secure an assortment of different-diameter pieces of round stock. Mark these into ¾″ pieces and proceed to cut them. See Fig. 131.

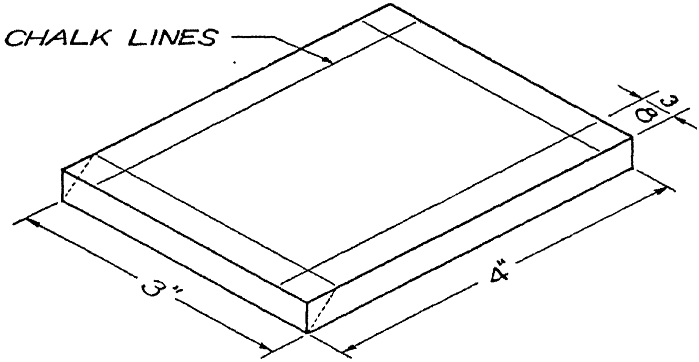

Fig. 132. Practice Cut No. 3—Beveling

Practice Cut No. 3

Secure a piece of steel 3″ x 4″, ¼″ or greater in thickness. Draw a ⅜″ line around inside the four edges. With the correct cutting tip, bevel these four edges. See Fig. 132.

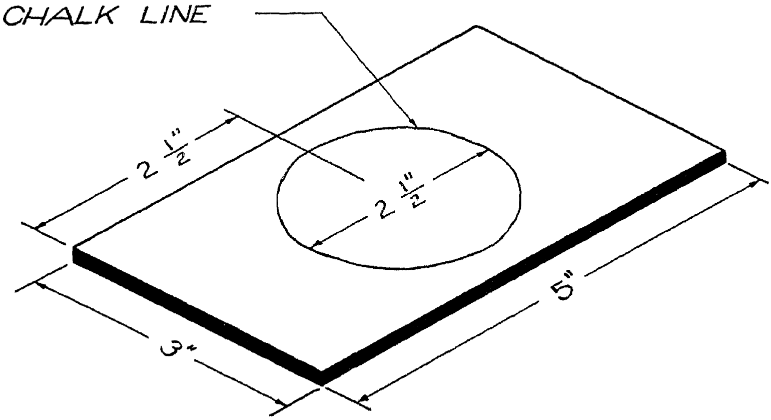

Fig. 133. Practice Cut No. 4—Cutting Holes

Practice Cut No. 4

Secure a piece of steel plate 3″ x 5″ of any desired thickness. Draw an opening as shown in Fig. 133 and cut.

Practice Cut No. 5

Secure a number of pieces of scrap cast iron and practice cutting them.

QUESTIONS

1. What causes metal to rust?
2. What principle makes possible the cutting of metal by means of oxygen and acetylene?
3. Describe the process for lighting and adjusting the flame for a cutting torch.
4. What is the function of the high-pressure oxygen valve?
5. How does the cutting tip differ from the welding tip?
6. What governs the pressure of oxygen and acetylene that must be used for cutting?
7. As a general rule where should the cut be started? Why?
8. What aids may be used to facilitate an even cut?
9. How can one determine whether the cut is penetrating through the metal?
10. What happens when the cutting torch is moved too slowly?
11. What is the position of the torch when cutting round material?
12. How is it possible to make a bevel cut with a cutting torch?
13. Describe the operation followed in piercing holes with a cutting torch.
14. What type of flame is used for cutting cast iron?
15. How is the torch held when cutting cast iron?
16. What torch motion is used for cutting cast iron?

Regulations for the Installation and Operation of
GAS SYSTEMS
FOR WELDING AND CUTTING *

Application of Rules

The following regulations are intended to apply to the installation and operation of all gas welding and cutting systems, and cover the use of all gases used for fusion welding and oxygen cutting. They also provide for the storage of calcium carbide and gases used in these processes.

They do not apply to systems in or upon cars or other rolling stock or upon vessels, to use in wrecking or for emergency, nor to plants devoted to the manufacture and compression of dissolved acetylene.

In the application of these regulations only standard equipment such as blow pipes, torches, regulators, acetylene generators, etc., as have been examined and tested and found to be safeguarded as far as practicable, shall be used.

All cylinders used for the storage of compressed gases shall be constructed in accordance with Interstate Commerce Commission regulations effective at the date of their manufacture, and charged with gas in accordance with Interstate Commerce Commission regulations. All cylinders shall be marked according to Interstate Commerce Commission requirements.

Acetylene Generation: Stationary Generators

1. *Approved and Marked Generators to Be Used.*

Generators shall be of approved construction and shall be plainly marked with the maximum rate in cubic feet of acetylene per hour for which they are designed, the amount or weight and size of carbide necessary for a single charge, the manufacturer's name and address, and the name or number of the type of machine.

2. *Rating of Generators.*

Generators shall not be used at rates in excess of those for which they have been specifically approved and marked. Unless specifically approved for higher ratings, carbide-feed machines for this service may properly be rated at one cubic foot per hour per pound of carbide, whereas with water feed machines, the rating shall not exceed one-half this amount.

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NOTE: Single automatic generators used as the sole acetylene supply should be of sufficient capacity to furnish a continuous supply of gas for at least one working period. Where more than one automatic generator or duplex machine is installed, permitting alternate use and recharging without affecting the continuity of the gas supply, the capacity of the generator or generators in service should be sufficient to supply, within the marked hourly ratings, the total demand for gas.

3. *Location of Generators.*

While generators, especially in closely built-up districts, should preferably be placed outside of buildings in generator houses constructed and located in compliance with Section 4, below, the installation of standard generators within buildings in accordance with these rules is permitted. Attention is drawn, however, to the prohibition of acetylene generators within buildings in certain districts by local authorities or by local inspection departments.

4. *Outside Generator Houses.*

a. No opening in any outside generator house shall be located within 5 feet of any opening in another building. Generator houses shall have natural light during daylight hours.

b. Generator houses should preferably be constructed of noncombustible material; they shall be well ventilated.

c. The heating shall be by steam, hot water, or other indirect heating system; the furnace shall be so located that no flame or fire is in or near the generator enclosure. Electric heaters shall not be employed.

d. Where artificial lighting is necessary, it shall be restricted to electricity. All electrical installations for light or power shall be in conformance with the requirements of Article 32 of the National Electrical Code.

5. *Inside Generator Rooms or Compartments.*

a. The installation of acetylene generators within buildings shall be restricted to buildings not exceeding one story in height; provided, however, that this shall not be construed as prohibiting such installations on the roof or top floor of a building exceeding such height.

b. Where generators are installed inside buildings, they shall be enclosed in a separate room or compartment of ample size. The walls or petitions, floor, and ceiling of such room or compartment shall be of one of the types of construction listed below. Walls or partitions shall be continuous from floor to ceiling and, except in cases where the compartment is provided with its own roof, shall be securely anchored.

Gypsum or cement plaster at least ¾″ thick on metal lath on each side of a stud partition.

Expanded metal lath encased in solid cement plaster not less than 2½″ thick.

Reinforced concrete.

Brick.

Tile, gypsum, or concrete block (cement plaster on each side to a thickness of ¼″).

c. Openings from generator room or compartment to other parts of the building shall be protected by a fire door classified and labeled as suitable for use in Class B situations as defined in the Regulations for the Protection of Openings in Walls and Partitions against Fire. The door shall be of the swinging type and close into a rabbet, or otherwise be made tight to prevent passage of flame around edges; it shall be self-closing, and, if fastened open, shall be arranged to close automatically in case of fire originating inside or outside of generator room or compartment. Windows if provided in partitions shall be protected by wired glass in approved metal frames.

d. A portion of the exterior walls equal to not less than 10 per cent of the combined areas of the enclosing walls shall be of light, noncombustible material, preferably thin glass. Thin glass skylights may be accepted in part or entirely in lieu of the glass area or its equivalent, provided the required percentage of venting area is thus obtained.

e. The inside generator room or compartment shall be adequately ventilated to the open air and so located as to afford natural light during daylight hours.

6. *Installation.*

The foundation shall be so arranged that the generator will be level and no unequal strain will be placed on the generator or its connections.

7. *Space About Generator.*

The space around the generator shall be ample for free and unobstructed operation, and permit ready adjustment and charging without portable artificial

8. *Ventilation of Generator Rooms or Compartments.*

The space about generators shall be well ventilated, preferably by some system which affords continuous ventilation. All practical means which will prevent the accumulation of a mixture of gas and air in case of leakage should be employed.

9. *Protection Against Freezing.*

Generators shall be placed where water will not freeze. No salt or other corrosive chemical is permissible as a protection against freezing.

10. *Water Supply Connection.*

Except when generators are provided with an adequate open overflow, water shall not be supplied through a continuous connection to the generator. The supply pipe shall terminate not less than 2 inches above the regularly provided opening for filling so that the water can be observed as it enters the generator.

11. Drain Connection.

Machines of the carbide-feed type shall not be fitted with continuous drain connections leading to sewers, but shall discharge through an open connection into a suitably vented outside receptacle which may have such connections.

NOTE: An open connection for the sludge draw-off at the generator is desirable to enable the operator to observe leakage of generating water from the sludge cock.

12. Generator Piping: Escape or Relief Pipes.

a. Each generator shall be provided with an escape or relief pipe of standard, full-weight galvanized iron or steel.

b. The escape or relief pipe shall be substantially installed without traps and so that any condensation will drain back to the generator.

c. The escape or relief pipe shall be carried to a suitable point outside the building and shall terminate in an approved hood or bend located at least 12 feet above the ground and as far as practicable from windows or other openings into buildings and from flues or chimneys. The hood or bend shall be so constructed that it cannot be obstructed by rain, snow, ice, insects, or birds.

d. Piping as far as possible shall be arranged so that any moisture will drain back to the generator. If low points occur of necessity in any piping, they shall be drained into drip pots normally closed with screw caps or plugs. No pet cocks shall be used.

e. Outside piping connecting generator with buildings shall be graded to the lowest point outside of buildings, and where condensation is not provided for the piping draining into the generator, a drip shall be provided at such lowest point to take care of condensation. This drip shall be so constructed as to permit draining or pumping out the condensate at necessary intervals.

Nonautomatic Generators

In addition to the foregoing rules which apply, nonautomatic generators shall comply with the following requirements:

13. Nonautomatic generators shall not be used for generating acetylene directly at pressures exceeding 1 pound per square inch, and all water overflows shall be visible.

14. Gas Holder.

a. The gas holder shall be constructed in a standard manner on the gasometer principle, the bell being suitably guided. The gas bell shall move freely without tendency to bind and shall have a clearance of at least 2 inches from the shell.

b. The gas holder may be located in the generator room or in a connecting room. In order to prevent collapse of the gas bell due to vacuum, the gas holder shall be so installed as to prevent the withdrawal of gas therefrom by compressor or booster pump when the gas bell has landed.

c. When not located within a heated building, gas holder seals shall be protected against freezing.

d. If inside building, the arrangement shall be such that generator feeding mechanism will be stopped before gas holder reaches the upper limit of its travel, which would permit escape of gas from the gas holder.

e. Except when connected with more than one generator, the gas capacity of the gas holder shall be not less than one third the aggregate hourly consumption therefrom.

f. Where acetylene is used in the shop directly from the gas holder, without increase in pressure at some points, and with increase in pressure by a compressor or booster pump for other points, separate, hydraulic back pressure valves shall be used in the supply lines. The main, low-pressure, hydraulic back pressure valve shall be between the gas holder and the shop line and the medium-pressure, hydraulic back pressure valve shall be between the compressor or booster pump and the shop line.

15. Compressor or Booster Pump.

a. Compressor or booster pump shall be of an approved type.

b. Electrical drive for compressor or booster pump shall be installed in accordance with the requirements of Article 32 of the National Electrical Code.

c. No compressor or booster pump shall be used which will raise the acetylene in the shop supply lines to a pressure exceeding 15 pounds per square inch gauge pressure.

d. The compressor or booster pump shall be equipped with a suitable device which will relieve pressure exceeding 15 pounds per square inch to the open air or by returning the gas to the inlet side or to the gas supply source.

16. Maintenance and Operation.

a. Generator rooms shall not be open to unauthorized persons.

b. In the care of generators, when the charge of carbide is exhausted or any carbide added, the generating chamber shall always be thoroughly cleaned, renewing the water supply in accordance with the instruction card furnished by the manufacturer.

c. When recharging carbide-feed generators, the following order of operation shall be strictly observed:

1. Clean out generating chamber.
2. Immediately fill the generating chamber with water.
3. See that water seals are at proper level.
4. Fill hopper with carbide. Never attempt to introduce carbide until after the generating chamber is properly filled with water.
5. Immediately purge air mixture in accordance with instruction card furnished by manufacturer.

Charging at other than daylight hours is permitted where generator room is lighted by protected, vapor-proof electric lights only, as specified by the National Electrical Code.

d. When generators are not in use, the water chamber shall be kept full if any carbide remains in the hopper.

e. Whenever repairs are to be made or the generator is to be charged or carbide is to be removed, the water chamber shall be full during such operations to avoid the danger of explosive mixtures of air and gas within the water space and also to prevent dropping fresh carbide into insufficient water. Previous to making repairs involving welding, soldering, or any other operation liable to produce a spark, the carbide charge and feed mechanism, where necessary to avoid wetting them, shall be completely removed and all acetylene expelled by completely flooding the shell with water.

f. Blow-off or relief valves shall be regularly inspected to insure proper functioning and set to blow off at a pressure not in excess of 15 pounds per square inch.

g. Solid residuum or exhausted material shall never be deposited in sewer pipes or near any combustible material.

h. The carbide added each time the generator is recharged should be sufficient to refill the space provided for carbide without ramming the charge. No steel or other ferrous rammer or tool shall be used in distributing the charge.

Portable Acetylene Generators

17. General.

a. The apparatus shall be of a type specifically approved for that purpose.

b. They shall not be used within 10 feet of combustible material other than the floor.

c. They shall not be used in rooms of total volume less than 35 times the nominal aggregate gas-generating capacity of all such generators in the room.

d. They shall not be placed where water will freeze. No salt or other corrosive chemical is permissible as a protection against freezing.

18. Operation and Maintenance.

a. They shall be cleaned and recharged and air mixture blown off outside buildings. Special exceptions may be granted by the Inspection Department having jurisdiction, in large-area, well ventilated, one-story buildings.

b. They shall not when charged be moved by crane or derrick.

c. When not in use they shall not be stored in any room in which open lights or fires are used unless free of carbide and thoroughly purged of gas. Storage rooms shall be thoroughly ventilated.

Service Piping Systems for All Gases

19. General.

In systems intended for a maximum working pressure in excess of 100 pounds per square inch, the piping shall be extra heavy.

20. Inside Piping.

a. Except as provided in Section *19,* inside piping shall be standard, full weight. Joints shall be welded or made up with substantial threaded fittings. Wrought iron or steel pipe only shall be used for acetylene.

b. Inside piping may be placed above or below ground. If above ground, such piping shall be adequately safeguarded against mechanical injury and vibration. If underground, piping may be placed in the same trench or ventilated duct with oxygen pipe lines, but under no circumstance shall an oxygen pipe be placed in the same trench or duct with an oil pipe line.

21. Outside Piping.

a. Except as provided in Section *19,* outside piping shall be standard, full weight. Joints shall be welded or made up with substantial, threaded fittings. Only wrought iron or steel pipe shall be used for acetylene. All piping shall be covered or painted with a suitable, corrosion-resisting material.

b. Outside piping may be placed above or below ground. If above ground, such piping shall be adequately safeguarded against mechanical injury and vibration. If placed underground and covered with fill, piping shall be below the frost line. Underground piping may be placed in ventilated ducts when containing oxygen pipe lines, but under no circumstances shall an oxygen pipe line be placed in the same duct with an oil pipe line.

c. Outside piping shall be run as directly as possible, carefully protected against injury, and the pipes pitched to the low point without sags, proper allowance being made for expansion and contraction, jarring, and vibration.

d. Pipes leading to the surface of ground shall be cased or jacketed where necessary to prevent loosening or breakage.

e. Gas cocks or valves shall be provided for all buildings at points where they will be readily accessible for shutting off gas supply to building in any emergency. There shall also be provided a shut-off valve in the discharge from the generator, gas holder, manifold, or other source of supply.

22. Testing.

All piping shall be tested and proved tight at 1½ times its maximum working pressure, and shall be thoroughly purged of air before being placed in service.

23. Oxygen Piping: Special Requirements.

a. All fittings and lengths of pipe for service lines shall be hammered before assembly to free them from scale. They shall be washed out with a suitable noninflammable solution which will effectively remove grease and dirt. After assembly they shall be thoroughly blown out to remove foreign materials. Carbon tetrachloride, caustic soda solution, and trisodium phosphate have been found effective cleaning agents for this purpose.

b. Screw joints shall be made up with glycerine and litharge; excessive use of glycerine shall be avoided.

24. Painting.

a. All oxygen pipe lines shall be painted one color, preferably green, and all fuel gas pipes a different color. Where more than one fuel gas is employed, the pipe lines supplying the different fuel gases shall be painted distinctive colors.

b. A color chart indicating the colors employed for this purpose shall be prominently displayed.

25. Coupling of Cylinders for Direct Supply to Blowpipes.

When it is necessary to simultaneously discharge gas from a number of cylinders through a common regulator, in order to provide sufficient volume of gas for heavy work, the coupler block and coupler arms used for connecting the cylinders with a common regulator shall be of substantial design and capable of safely withstanding any pressure to which they may be subjected in operation. When acetylene cylinders are coupled, approved flash arresters shall be inserted between each cylinder and the coupler block.

The aggregate gas capacity of fuel gas cylinders coupled shall not exceed 2000 cubic feet for any one group of coupled cylinders.

Manifolding of Cylinders to Headers for Shop Pipe-Line Supply Systems.

26. Acetylene.

a. Headers shall be constructed of double extra heavy piping not exceeding 1¼″ pipe size. Fittings in header, if used, shall be extra heavy. Headers shall be provided with shut-off valves at each point where a cylinder is to be connected. The use of copper pipe or fittings shall be prohibited.

b. Leads from header valves to cylinder valves shall be constructed of steel tubing, block tin, or an approved composition pipe, and shall be capable of standing a pressure of 1000 pounds per square inch. Copper tubing shall not be inserted between each cylinder and each header valve.

c. The discharge opening from the header shall be equipped with an approved regulator and shall be adjusted so that acetylene at a pressure in excess of 15 pounds per square inch will not be delivered to the shop supply piping system.

d. A flash arrester of the low pressure type, or a suitable hydraulic seal, shall be installed between the regulator at the discharge of the header and the shop piping.

e. Except as provided in Section *26f*, acetylene cylinders connected to a header inside a building shall be limited to a total gas capacity not exceeding 2000 cubic feet.

f. Where it is necessary to connect to a manifold header acetylene cylinders having an aggregate gas capacity in excess of 2000 cubic feet, the header shall be located in a special outside building or in a separate room constructed in accordance with the provisions of Section *5b* and *5c*.

g. Special buildings or rooms, if provided, shall have no other occupancy except that they may be used for the storage of cylinders containing fuel gases or calcium carbide; such buildings or rooms shall have no open flame for heating or lighting and shall be well ventilated.

h. Where a system of shop piping is supplied with acetylene from cylinders connected to a header, an approved service regulator or hydraulic seal shall be used at every point in the shop piping system where acetylene is drawn off to supply a blowpipe torch or other gas-consuming device.

i. All manifold systems shall be capable of withstanding a test pressure of 1000 pounds per square inch after assembly.

27. Liquified Fuel Gases and Nonliquefied Fuel Gases other than Acetylene.

The same rules as for acetylene manifolds shall apply, except as follows:

a. Flash arresters need not be provided between cylinders and header valves.

b. Copper or copper alloy tubing may be used for leads between header valves and cylinder valves.

c. Manifold systems shall be capable of withstanding a test pressure of 1½ times the charging pressure.

28. Oxygen.

a. All sections of header shall be freed of rust and all combustible matter before assembly.

b. Fittings for header shall be of substantial design and may be welded to header or screwed and soldered or screwed only, with use of litharge and glycerine.

c. The leads or connections attaching cylinders to header shall be constructed of annealed brass, bronze, or copper.

d. Headers, fittings, and leads shall be capable of withstanding a pressure of 3000 pounds per square inch.

e. Headers, fittings, and leads after assembly shall be washed out with a solution of caustic soda and water or with carbon tetrachloride.

NOTE: It is advisable for users of oxygen headers or manifolds to purchase them from and have them installed by reliable manufacturers, familiar with the proper shop practice with reference to their construction and installation.

Storage of Cylinders

29. *Fuel Gases.*

a. Cylinders inside a building, except those in actual use or attached ready for use, shall be limited to a total capacity of 2000 cubic feet.

b. For storage in excess of 2000 cubic feet total capacity of cylinders, a separate room or compartment as provided for by Section *5b* and *5c* shall be provided, or cylinders shall be kept outside or in a special building. Special buildings, rooms, or compartments shall have no open flame for heating or lighting, shall be well ventilated, and shall have no other occupancy, except that they may be used for the storage of calcium carbide.

c. All cylinders shall be protected against excessive rise in temperature. Cylinders may be stored in the open but in such case should be protected against extremes of weather. During winter, cylinders stored in the open should be protected against icy precipitations. In summer, cylinders stored in the open should be screened against the continuous direct rays of sun in desert or other localities where extreme temperatures prevail.

d. Cylinders permitted inside buildings shall be stored remote from highly combustible material and in locations where they are not liable to mechanical injury or tampering by unauthorized persons.

e. Cylinders of dissolved acetylene shall always be stored standing upright with the valve end up.

f. Empty cylinders in storage shall have their valves closed and shall have valves closed when shipped.

30. *Oxygen.*

a. Cylinders of oxygen shall never be stored in the same room or compartment used for the storage of calcium carbide or cylinders containing fuel gases, or in an acetylene generator compartment.

b. Cylinders of oxygen, except those in actual use, shall be stored away from highly inflammable material, especially oil, grease, or any substance likely to cause or accelerate fire.

c. Cylinders of oxygen shall be stored in locations where they are not likely to be struck by passing or falling objects.

d. Oxygen cylinders should be protected against excessive rise of temperature. Cylinders may be stored in the open but in such cases should be protected against extremes of weather. During winter, cylinders stored in the open should be protected against accumulations of ice or snow. In summer, cylinders stored in the open should be screened against continuous direct rays of sun in desert or other localities where extreme temperatures prevail.

31. *Storage of Calcium Carbide.*

a. Calcium carbide in quantities not to exceed 600 pounds may be stored, when contained in approved metal packages, inside buildings, provided that the place of storage be dry, waterproof, and well ventilated, and also provided that all but one of the packages of each size of carbide shall be sealed. The seals shall not be broken as long as there is carbide in excess of one (1) pound in any other unsealed package of that size of carbide in the building.

b. When intended for other than merchandising purposes, it is recommended that the quantities of carbide permitted under paragraph *a* be stored in the generator room and not elsewhere, unless a more suitable place can be provided.

c. Calcium carbide in excess of 600 pounds but not in excess of 5000 pounds may be stored in a separate room or compartment inside a one-story building containing other occupancy, provided such room or compartment is constructed in accordance with the provisions of Section *5b* and *5c* and without cellar or basement underneath such carbide storage section. This room or compartment may also be used for other storage of fuel gas cylinders. Adequate ventilation shall be provided. Not to exceed 5000 pounds of calcium carbide may also be stored within an inside generator room or compartment of construction as prescribed by Section *5b* and *5c* when such generator room or compartment is located in a one-story building without cellar or basement underneath the generator section.

d. Calcium carbide in excess of 5000 pounds shall be stored above ground in one-story buildings without cellar or basement and used for no other purpose except for the storage of fuel gas cylinders. Calcium carbide in excess of 5000 pounds may be stored in outside generator houses.

Location of such storage buildings shall be outside congested mercantile or manufacturing districts.

Construction used shall be such as to insure a dry, waterproof building. Adequate ventilation shall be provided.

If storage building is of incombustible construction, it may adjoin other one-story buildings if separated therefrom by unpierced fire walls. If detached less than 10 feet from such building or buildings, there shall be no opening in any of the mutually exposed sides of such buildings within the 10-foot distance.

If the storage building is of combustible construction it shall not be within twenty (20) feet of any other one- or two-story building, nor within thirty (30) feet of any other building exceeding two stories.

e. Calcium carbide shall be contained in approved metal packages of sufficient strength to insure handling without rupture, and shall be provided with a screw top or its equivalent. They shall be constructed water- and air-tight without the use of solder, except at such points as it may be necessary to use this in order to close small crevices which cannot be otherwise sealed. Solder shall not be used on joints in such a manner that fire would disrupt the package.

f. Packages containing calcium carbide shall be conspicuously marked "Calcium Carbide—dangerous if not kept dry."

Storage of Welding Equipment

32. *General.*

Welding equipment such as regulators, blowpipes, hose, etc., when not attached to cylinders ready for use, shall be stored in clean locations away from grease and oil. Hose should be stored in cool locations, special care being taken that it is not laid on greasy floors or shelves where it is likely to absorb such materials.

33. *Hydraulic Seals.*

a. In low-pressure fuel-gas systems, including city gas, natural gas, etc., where the gas is supplied to the blowpipe or torch at a pressure not in excess of one pound per square inch, a hydraulic back-pressure valve shall be located at every point where gas is withdrawn from the piping system. A stopcock or valve shall be inserted in the system between each hydraulic valve and the piping system.

b. In fuel gas systems where the gas is supplied to blowpipes at a pressure in excess of one pound per square inch, an approved service regulator, check valve or hydraulic seal shall be employed at every point where gas is withdrawn for use.

34. *Regulators.*

a. Regulators or automatic reducing valves shall be used only for the gas for which they are intended.

b. When repairs to regulators are necessary, such repairs shall be performed only by skilled mechanics properly instructed in the work.

NOTE: Working or low-pressure gauges attached to regulators should be periodically tested to insure their accuracy.

c. Union nuts and connections on regulators shall be regularly inspected to detect faulty seats which may cause leakage of gas when the regulators are attached to the cylinder valves. When damaged connections are found, they shall be immediately removed from service.

35. *Hose.*

a. The hose necessary to connect blowpipes to gas outlets shall be of a good quality of rubber having a sufficient number of plies of fabric to withstand the service for which it is employed.

NOTE: While in some classes of light work it is desirable to have a light and flexible hose, this hose shall be capable of withstanding a hydrostatic pressure of 200 pounds per square inch held for 5 minutes. For heavier service and for hose carrying gases under pressure higher than 15 pounds per square inch, a hose capable of withstanding a test pressure of 400 pounds per square inch shall be used.

b. Hose connections shall be made through substantial fittings and clamped or otherwise securely fastened to these connections in such a manner as to withstand without leakage a pressure twice as great as may be obtained through regulating valves provided on the system.

36. *Operation of Welding Equipment.*

Welding operators shall follow the procedure outlined by the manufacturer of the apparatus in use, in so far as they deal with the sequence of operations in lighting, adjusting, and extinguishing blowpipe flames and in connecting up the apparatus to the sources of gas supply.

General Precautions

37. *Failure to observe the following precautions may endanger life as well as property.*

a. Mixtures of combustible gases and air are very explosive and shall be carefully guarded against. No device or attachment facilitating or permitting mixture of air or oxygen with combustible gases prior to consumption, except at the burner or in a standard torch or blowpipe, shall be allowed unless approved for the purpose.

b. Under no conditions shall acetylene be generated or utilized at a pressure in excess of 15 pounds per square inch gauge pressure. This requirement is not intended to apply to the storage of acetylene dissolved in a suitable solvent in cylinders manufactured according to Interstate Commerce Commission requirements.

c. The use of liquid acetylene is prohibited.

d. Tests of any piping systems or acetylene generators for leaks shall not be made with a flame. Soapy water shall be used for this purpose.

e. When purging combustible gas lines of air, lights shall not be applied to uncapped openings.

f. Metal tools for opening carbide containers or for making repairs shall be used with caution to avoid striking a spark. Such a spark may cause ignition if a gas-and-air mixture is present.

g. No acetylene generator shall be moved by a crane or derrick while charged with carbide.

h. Every possible precaution shall be taken to prevent oxygen from coming in contact with oil or grease.

i. Under no circumstances shall acetylene gas be brought in contact with unalloyed copper except in a blowpipe or torch.

j. Under no circumstances shall cylinders containing compressed gas be lifted with electro-magnets.

k. Cylinders not provided with handwheel valves shall have spindle keys on valve spindles or stems while cylinders are in service.

l. Where welding or cutting is being performed in establishments having wooden floors, the floors shall be covered with metal or other suitable noncombustible material where sparks or hot metal are liable to fall.

m. Oil or grease shall never be permitted to come in contact with oxygen cylinders, valves, regulators, or other fittings. Oxygen cylinders and apparatus shall not be handled with oily hands, gloves, or greasy materials.

n. Oxygen shall never be used from a cylinder unless the oxygen cylinder is provided with a pressure-regulating device intended for that purpose only.

o. Fuel gas shall never be used from cylinders through blowpipes or other devices equipped with shut-off valves on the acetylene-supply connections without reducing the pressure through a suitable regulator attached to the cylinder valve.

NOTE: Pressure-adjusting screws on regulators shall always be fully released before the regulator is attached to a cylinder and the cylinder valve opened. Always open the valve on cylinders of compressed gas slowly.

p. Before a regulator is removed from a cylinder valve, the cylinder valve shall always be closed and the gas released from the regulator.

q. Every care shall be taken to prevent sparks or flame from welding or cutting torches coming in contact with cylinders.

r. If cylinders containing fuel gases are found to have leaky fittings, the cylinders shall be taken into the open and slowly drained of gas. When the valves on the cylinders leak, a regulator shall be immediately attached to the valve to stop leakage, or the cylinder shall be removed to the open and slowly drained of gas.

NOTE: The owner of the cylinder should be advised of the defect so that it may be repaired when returned to him. It is advisable to tag the cylinder in such a way as to indicate the defect.

s. Never attempt to transfer any gas from one cylinder to another or to mix gases in a cylinder.

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